In this Issue: The Fort Garry Terminal at Winnipeg. Moisture in Compressed Air Apparatus.—Design of a Railway Viaduct Over the Chattahoochee River, Seaboard Air Line Railway.—Tests of Air Lift Pumps.

ENGINEERING NEWS

Volume 59. No. 25.

220 Broadway, NEW YORK, THURSDAY, JUNE 18, 1908.

$5.00 per Year. Single Copies, 15 Cents.

FOR REINFORCING CONCRETE

"Hudson" Steel Bar

Immediate Delivery

High Elastic Limit

Great Strength

HUDSON STRUCTURAL STEEL CO.

136th Street and Southern Boulevard

New York

"The best not the cheapest."
Our "Data" tell all about

"BESSEMER PAINT"

Sole Manufacturers

RINALD BROTHERS

1142-1146 N. Hancock St., Philadelphia

ALMA

PORTLAND CEMENT

STANDARD BRAND OF MIDDLE WEST

Specially Adapted to All Reinforced Concrete and High-Class Work

ALMA CEMENT COMPANY

Wellston, Ohio

DR. CHARLES F. McKENNA

Consulting Chemist and Chemical Engineer
Expert in Technology and

Testing of Materials

OFFICE
FULTON BUILDING, HUDSON TERMINAL
50 CHURCH STREET, NEW YORK CITY

"Cayuga" Portland

CEMENT

ALWAYS UNIFORM

Made from the best cement rock and used during the past seven years in the best engineering work.

MANUFACTURED BY

CAYUGA LAKE CEMENT COMPANY

ITHACA, N. Y.

LOOMIS FILTERS

Improved System — Established 1880 — Results Guaranteed

LOOMIS-MANNING FILTER CO.

Main Office 828 Land Title Bldg., Philadelphia Pa.

New York — Boston — Baltimore — Washington — Buffalo — Chicago

LATROBE

Crusher Rolls and Shells

Forged, Punched and Rolled from SOLID STEEL INGOTS

RAILWAY STEEL-SPRING COMPANY

General Offices

Cortlandt Bldg., 30 Church St., New York

HYDREX

THE TOUGHEST, STRONGEST, MOST ELASTIC WATERPROOFING FELT

"The Membrane Method"

HYDREX FELT AND ENGINEERING CO., Engineers and Experts in Waterproofing Problems

Chicago Washington East Walpole, Mass. See page 3 last issue 120 Liberty Street New York

Sewer Pipe, Flue Linings, Etc., Etc.

3 TO 36 INCH

ST. MARYS SEWER PIPE CO.

ST. MARYS, ELK CO., PA.

FOR ALL CITY SEWERS

GLAZED CLAY SEWER PIPE

Better and cheaper than brick or other material. Demand constantly increasing. We have it in 27, 30 and 36-inch, and all smaller sizes. In business fifty years. Write the manufacturer.

EVENS & HOWARD FIRE BRICK COMPANY, St. Louis, Mo.

IN MAKING PLANS for Sewer Construction don't ignore our large sizes of

VITRIFIED PIPE

27, 28, 30, 33, and 36-inch

NEARLY 100 CITIES have used it and prefer it, because it is cheap, it is clean; it is durable; it is convenient; it is modern

BLACKMER & POST PIPE CO., St. Louis, Mo.

Vitrified Pipe—Double Strength Extra Heavy Culvert Pipe
All Sizes

MANUFACTURED FROM SHALE

W. S. DICKEY CLAY MFG. CO.

Kansas City, Mo.

MACOMB SEWER PIPE CO. MACOMB, ILL.

Superior Vitrified Sewer Pipe — Double Strength Extra Thick Culvert Pipe

ALL SIZES MONMOUTH SEWER PIPE MADE BY MONMOUTH MINING & MFG. CO., Monmouth, Ill.

WRITE TO OUR NEW YORK OFFICE FOR A FREE COPY. SEVENTH EDITION. REVIEW OF

TECHNICAL PAINTS FOR METAL

Established 1876 Works Williamsport Pa. NATIONAL PAINT WORKS Main Sales Office 100 William St., New York

SMITH MIXER

See our advertisement on page 53

"WHITING" Cupolas, Air Hoists, Electric Travelers, Tumblers, Ladles

FOUNDRY EQUIPMENT

EFFICIENT, ECONOMICAL — Trucks, Turntables, Elevators

Complete Foundry Plants CONSTRUCTED FOR SERVICE

WHITING FOUNDRY EQUIPMENT COMPANY, - HARVEY, ILL.

EVERY DOLLAR SPENT FOR

TEXTOL

CONVEYOR BELTING

returns 100 cents' worth of service.

Rugged construction of the best material, iron-clad in resistance to strain, exposure and wear, sold at the lowest possible prices, insures these results.

Do not wait until you need your next belt, but write us now and get posted.

NATIONAL BELTING CO.

LAWRENCE, MASS.

"SIROCCO"

BLOWERS

For Mines, Ships, Buildings

Patented in U. S. A., 1900, 1901, 1902, 1903, 1904, 1905, 1906

SIROCCO ENGINEERING CO.

WORKS: TROY, N. Y.

138 CEDAR STREET NEW YORK

PROPOSALS

See pages 43 to 50

"Lehigh" Portland

CEMENT

High Tensile Strength — Finely Ground
Light and Uniform in Color
Recommended for High-Class Engineering Work

Manufactured by

LEHIGH PORTLAND CEMENT CO.

ALLENTOWN, PA

WESTERN OFFICE

725 Rockefeller Building. CLEVELAND OHIO

Will Furnish and Erect in United States and Foreign Countries

Wooden Stave Pipe

EXCELSIOR WOODEN PIPE CO.

Offices: San Francisco and New York

Advertisement is on page 14.

P-A-I-N-T—PAINT

"CARBONKOTE"

Preserves Steel and Iron Surfaces
Waterproofs Concrete — Booklet on Request

NUBIAN PAINT AND VARNISH CO.

41 Park Row, New York — CHICAGO

THE PULSOMETER STEAM PUMP

See our advertisement on page 8

PIPE DIP

Brick Filler—Roofing—Paints

AMERICAN ASPHALTUM AND RUBBER CO.

Woman's Temple, Chicago

The paint of standard quality for permanent protection of steel, iron and wood.

FEROX

(TRADE MARK)

HAMMOND, BOYNTON PAINT AND CHEMICAL CO.

Main Office and Factory Norwich, Conn. — New York Office 1418 Flat Iron Building

MAKE TIGHT STEAM JOINTS BY USING CORRUGATED COPPER GASKETS FOR FLANGED PIPES CYLINDERS, CHESTS, Etc.

Samples and Circulars free

UNITED STATES MINERAL WOOL CO., 140 CEDAR STREET, NEW YORK CITY

Buyers' Reference, Page 27

Alphabetical Index of Advertisers, Page 31

THE BEST WOOD PIPE
WYCKOFF WOOD PIPE COMPANY
SEND FOR OUR CATALOG **ELMIRA, N. Y., U. S. A.**

Eliminate Uncertainties From Your Estimate

We supply CORRUGATED BARS bent as required, ready to place in the forms, thus eliminating the tedious and expensive bending of stirrups and bars on the job.

And Save Money in the Installation of the Steel

BY USING

Economy Unit Frames

Don't "wire and tie" your profits away when you can do the placing in one-half the time and at one-fifth the cost by using Economy Unit Frames.

You ought to know all about Economy Unit Frames and we suggest that you write for our Descriptive Booklet B-3

EXPANDED METAL AND CORRUGATED BAR CO.
FRISCO BLDG. ST. LOUIS

WRITE FOR OUR BULLETINS ON DESIGNING METHODS

ENGINEERING NEWS

A JOURNAL OF CIVIL, MECHANICAL, MINING AND ELECTRICAL ENGINEERING

Vol. 59. No. 25. 220 Broadway, New York, June 18, 1908.

TABLE OF CONTENTS.

	Page.
LEADING ARTICLES:	
Three Tramway Bridges on the Coal-Storage Dock of the Berwind-White Coal Mining Co., Superior, Wis. (illustrated); R. W. Wetherill	655
Some Detail Points in the Design and Construction of a Railway Viaduct (illustrated); Philip Aylett, Assoc. M. Am. Soc. C. E.	657
The Moisture in the Atmosphere and Its Effect on the Operation of Compressed Air Machinery, Especially Air Brake, Multiple-Unit Train Control and Train Signal Systems (illustrated); H. M.-Prevost Murphy	659
The Fort Garry Terminal; A Union Station at Winnipeg, Man. (with two-page inset); J. D. Matheson	663
Quenching Coke Without Water	666
Tests of an Air-Lift Pumping Plant and Experimental Studies of Air-Lift Pumps (illustrated)	666
Progress of Excavation on the Panama Canal (illustrated)	668
Tunnel Breakage, Outside of Prescribed Cross Section; Clinch Valley Division, Norfolk & Western R. R. (illustrated; Emile Low	668
Aerial Photography for Taking Bird's-Eye Views of Industrial Plants (illustrated)	669
Smoke Abatement in Chicago	669
Transplanting an 80-ft. Tree with a Locomotive Crane (illustrated)	670
A Motor-Driven Eraser (illustrated)	670
Advantage of Porous Brick in Brick Walls (illustrated)	670
Steel Rails for Present Service; Their Manufacture and Their Failures	673
The Work of the Lobnitz Rock Breaker in Sub-Aqueous Rock Removal	674
A Concrete Sidewalk Machine (illustrated)	677
Power Requirements of Railroad Shop Tools (illustrated); L. R. Pomeroy, Assoc. M. Am. Soc. M. E.	677
EDITORIAL	671
Moisture in Compressed Air Systems—The Second Trial of the Harrisburg Capitol Conspirators—The Floods of 1908 and River Regulation Engineering—The Michigan Pine Barrens.	
Concerning American Railway Management	671
LETTERS TO THE EDITOR	672
Where Work Should be Stopped on a Reinforced-Concrete Beam; Clinton L. Bogert—Some Misleading Authorities on Grillage Beams; R. F.—The Influence of Protective Coatings on the Corrosion of Iron and Steel; A. H. Sabin, Assoc. M. Am. Soc. C. E.—Notes and Queries.	
ENGINEERING NEWS OF THE WEEK	678
PERSONALS	680
ENGINEERING SOCIETIES	680

THREE TRAMWAY BRIDGES ON THE COAL-STORAGE DOCK OF THE BERWIND-WHITE COAL MINING CO., SUPERIOR, WIS.

By R. W. WETHERILL.*

The Superior-Duluth harbor, Lake Superior, around which practically every known method of storing coal is used, stands first in the world as a coal port. For shipments from the East it is easily the most advantageous distributing point for the Northwest, giving the longest water haul and a proportionately short rail haul. During the season of 1907 over 5,000,000 tons were unloaded from lake vessels on its docks.

There are now being operated about the harbor 20 coal docks with seven railroads diverging from them, and covering a rapidly-growing, coal-consuming territory. Of the 20 docks in use, five are practically new installations. The total nominal storage capacity of all is about 4,000,000 tons with a handling rate of more than 50,000 tons per day of ten hours. This, of course, permits them to handle more than their actual storage in a season, and such provision is desirable, as shipments are heavy during the fall months, navigation usually closing in December. The location of this port, combined with the unexcelled natural harbor, points toward a rapid and substantial growth. Coal forms the principal receipts and grain and ore the shipments. In view of the difficulties experienced by the railroads in transporting coal through the winter, the time is probably not far distant when auxiliary storage facilities at such places at Grand Forks or Fargo, North Dakota, will be desirable. Through these places, only 50 miles apart, but on different routes, probably 400,000 tons of coal now pass during an average winter, a haul of 320 miles from Superior. Such coal could probably be stored to the best advantage during the grain shipping season, when freight is wanted for the return trip.

Cable ways, dump cars and small tramways are mostly used among the older docks. Such equipment is admittedly expensive to operate, and hence must soon give way to more modern machinery. Dump cars and the "Dodge System"* are used to store anthracite coal, while tramways of some description form a part of nearly every bituminous plant, a number of them operating in conjunction with dump cars. In many cases, even on recent installations, it is necessary to handle the coal two or more times, both in storing and in reloading. Where dump cars are used the coal is dropped to the dock, causing more or less breakage, and the resulting packing is probably responsible for some of the coal fires that break out every season. It is conceded that every time bulk is broken there results an average loss into screenings of 5%, applying to both hard and soft coal.

There are very few plants that have at all good screening facilities. Lip screens up to 6 ft. in length are the rule. The time is at hand when attention must be given to handling the coal without breakage, and to properly preparing it when reloading. As a notable example of the development of these features to a high standard, in the following is given a description of the Berwind-White Coal Mining Co.'s new dock at Superior.

Early in 1907 the contracts were let by the Berwind-White Coal Mining Co. for a new coal dock, with the intention of completing it in time to fill it with coal before the close of navigation. August 15 was the day appointed to put the machinery into operation. The plant is of the bridge tramway type, as shown in Figs. 1 and

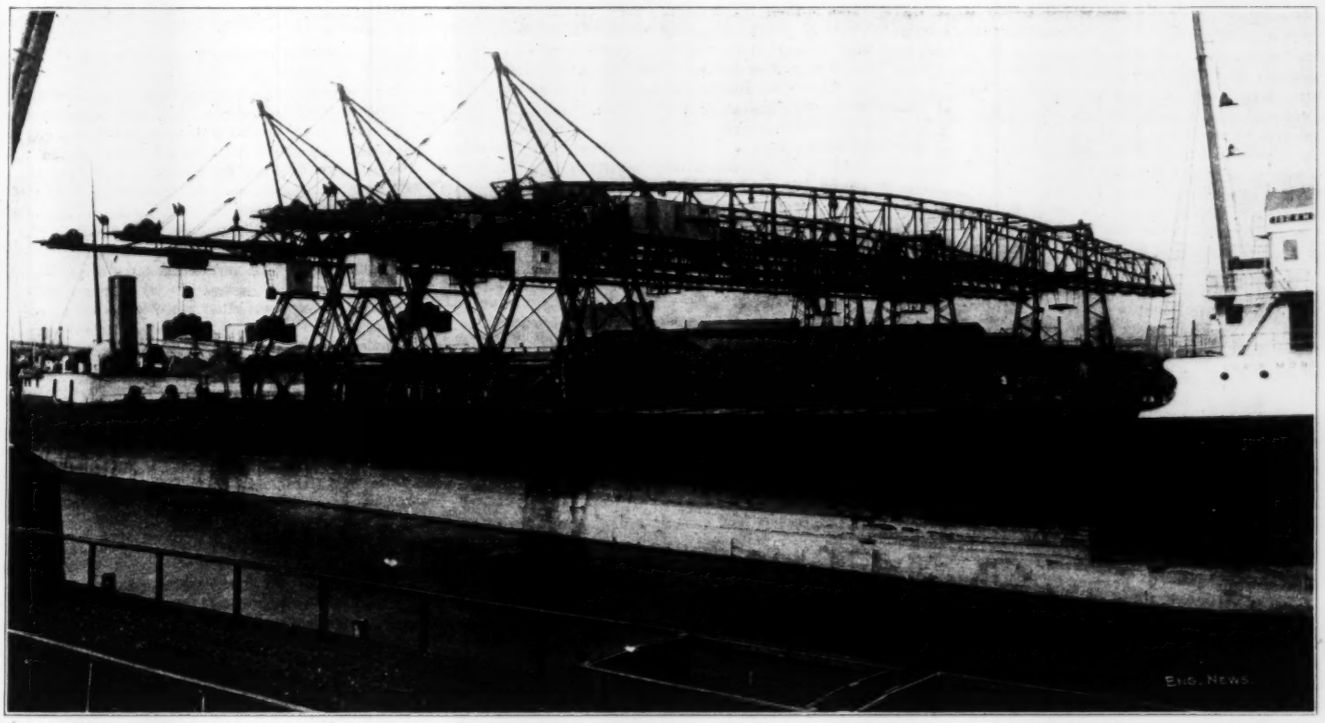


FIG. 1. THREE COAL-HANDLING, TRAMWAY BRIDGES AT SUPERIOR, WISCONSIN.
Designed, Built and Erected for the Berwind-White Coal Mining Co., by the Dodge Coal Storage Co., of Philadelphia.

*Dodge Coal Storage Co., Philadelphia, Pa.

[*The essential features of the coal-handling systems built under the patents of Mr. James M. Dodge, M. Am. Inst. M. E., with descriptions of several notable plants, were given in an article entitled "Some Recent Mechanical Coal Storage Plants," by Mr. W. G. Hudson, M. Am. Soc. M. E., in Engineering News, Aug. 29, 1907.—Ed.]

2, each one of the bridges having a total length of 506 ft. The span is 295 ft. c. to c. of towers; the cantilever is 125 ft., and the boom from the center of the front tower is 86 ft. Of the structural design the following points may be of interest. The weight of each front tower is 140,000 lbs., of each rear tower, 80,000 lbs., and of each bridge, 454,000 lbs. The chords are 16 ft. centers; the panels, 22 ft., and the trusses at the center of the bridge are 23 ft. high. The design permits of moving either tower 15 ft. out of line with the other. To accomplish this a king pin is used to connect the bridge to the front tower. A girder supported by the converging legs of the tower carries a similar one located between the upper chords of the bridge at the second panel point, and the king pin passes through the center of these girders. At the rear tower the bridge is suspended on 14 eyebars, 6 × 1-in. in section and 22 ft. long c. to c. of holes. There are seven bars on a side, outside of the bridge chords. The pins at the top of the bars are supported in a girder across the tower legs, over the bridge. The supporting girder in the bridge is on top of the lower chord. Side swinging due to wind is prevented by rubbing plates attached to the tower and bridge. When the towers are moved out of line, one set of bars inclines slightly backward and the other set forward.

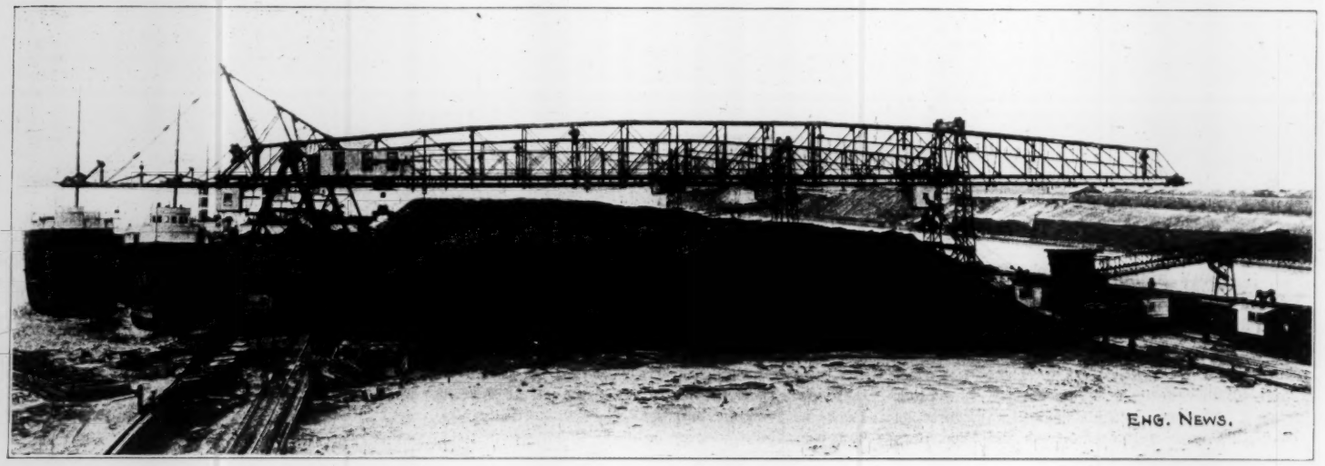


FIG. 2. SIDE VIEW OF COAL-HANDLING, TRAMWAY BRIDGES AT SUPERIOR, WISCONSIN.

The dead load, exclusive of machinery, for each truss is 90,000 lbs. at the front tower and 127,000 lbs. at the rear tower. The machinery load for each truss is 39,000 lbs. at the front tower and 7,000 at the rear. The chords are made up of latticed channels throughout except eight panels of the top chord which are covered with plate. The channels range from 10-in. 15-lbs. at the rear end of the top chord to 15-in. 50-lbs. in two panels of the bottom chord. The bottom chord is 57 ft. above the track elevation.

A three-ton automatic bucket is used, both for unloading boats and reloading into cars, though the design permits of the use of drag buckets for reloading, at the discretion of the operating company. Seven-eighth in. cast-steel wire cables are used for hoisting and operating the bucket. A ¾-in. cable is used to trolley the bucket along the bridge.

The trolley wagon, or carriage, supporting the bucket travels on 35-lb. T-rails laid on and hook-bolted, for adjustment, to the flanges of 15-in., 42-lb. I-beams.

To prevent sag in the cables on account of the length of the bridge, three "rope carriers" are used in each bridge. These are arranged to open for the carriage to pass through and close again to catch the sag in the ropes. They are operated through levers connected to a hinged section of the track, the track lowering under the weight of the bucket. They are very efficient, operate quietly, and a cable is rarely seen below them, so surely do they act.

The hoisting and trolleying drums are located in the forward end of the bridge, and are driven by alternating-current motors. The motor driving the trolley drum is also used for propelling the bridge lengthwise on the dock, and when used for this purpose, its power is transmitted through the bridge and down the tower legs by hollow shafting and steel gears. The trucks attached to the structural framing are designed to compensate for any unevenness in the tracks by a swiveling freedom.

By means of the auxiliary carriage, shown on the inclined track in the rear of the bridge, the reaving of the hoisting system becomes greatly simplified. The hoisting cable has one of its ends attached to the drum, the other end is carried through the bridge, passed around the upper sheave in the auxiliary carriage and dead ended at the upper end of the inclined track, making a two-part tackle. The other sheave in the auxiliary carriage takes the bight of the "hoisting loop," the two ends of which are dead ended on the power drums in the bucket housing, the sheave on the auxiliary carriage revolving as an idler only when trolleying. When the ends of the hoisting-loop cable wear out, they are cut off and compensated for by leaving out more at the dead end of the hoisting cable above referred to, allowance being made for this when new cables are put on. The track is considerably longer than the actual travel of the auxiliary carriage (which is the distance through which the bucket is hoisted) so that when the hoisting cable is made longer by letting out some at the dead end, it results in the travel of the carriage being further down the track. The holding cable is fastened at one of its ends to a drum and is passed along the under side of the bridge, through the main trolley wagon, a hoisting block attached to the bucket, and thence to a dead end at the rear of the bridge. No counterweights or tension carriages of any kind are required in this rope system. Of the two trolley cables, one end of each is attached to the spirally grooved drum and the other to the trolley wagon. A tightening device in the wagon maintains the proper tension. The trolleying speed is 1,000 ft. per minute.

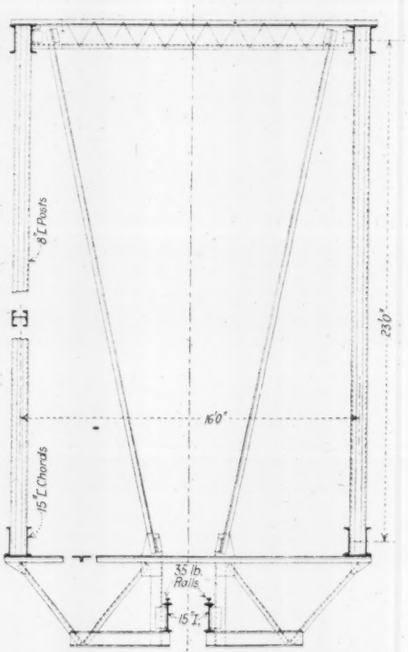


Fig. 3. Cross-Section at the Center of a Dodge Tramway Bridge.

The booms are hinged that they may be raised to permit of boats passing. The bridges can also be operated with the booms up to avoid delay when moving past boat masts.

There are two points of reloading. A hopper in the front tower is built without screens to chute coal either into box cars or gondolas by electrically operated chutes and gates. Under the cantilevers are screening towers and bridges, operated entirely independent of the tramways, and which are supplied with coal by either the tramways or locomotive cranes. The lump coal passes either into box cars or into gondolas, while the screenings are raised by a bucket elevator, carried over the tracks in a conveyor and stored along the outside of the dock, from where they can again be handled by either the tramways or cranes. This arrangement eliminates the usual large number of reloading bins and their attendant cost, thereby permitting the design of a few movable bins with much better screening facilities.

The tramways may be operated from either end, according to where the coal is being handled. Only one man is required to operate a bridge. The layout of tracks and storage area has the great advantage of keeping the weight of coal away from the edge of the dock without lost space. As a result the cribbing will remain in much better alinement.

Fig. 4 shows a double "contact post" used to transmit current to the various machines. The one shown is used to supply the bridges and a box car loader, being double sided. They are spaced every 16 ft. along the dock. Irregularities in the track alinement are compensated for by flexibly arranged collectors attached to the machines.

The power, 25-cycle, alternating current, used to operate the plant is furnished by the Great Northern Power Co. from their new water power development on the St. Louis River, above Duluth. It is transmitted to the dock at 13,000 volts, and there transformed down to 440, at which it is distributed to the various machines.

The machinery is designed to handle the three-ton buckets at the rate of one trip a minute from the boat to the dock or from the dock to the cars. On Sept. 26, a little more than a month after the plant was put into operation, the three

bridges made records of 520, 610 and 617 trips in a run of 8½ hours; a total of 1,747, or an average of 68.5 trips per hour per bridge. Since then occasional runs of between 90 and 100 trips in an hour have been recorded. With such increased size of bucket and speed in handling them, it has been found essential that the boat owners furnish boats that require the least shoveling to clean up if they wish to minimize their delays at the dock. It is poor economy for both the boat and dock owner to continue the use of some of the old coal carrying boats now on the lakes.

The three bridges were put into operation on Aug. 8, a week before the specified time. Dur-

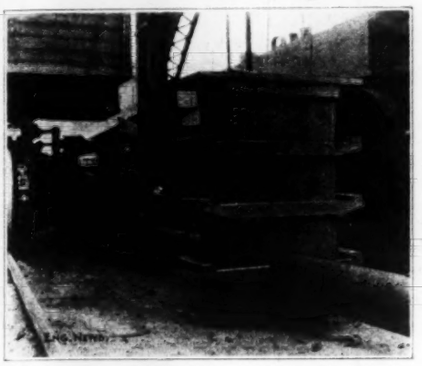


Fig. 4. Contact Posts and Collector Shoes for Transmitting Electric Current to Tramway Cranes at Superior, Wisconsin.

ing this time the complete mechanical and electrical equipment was manufactured, shipped to Superior and erected, and this was done at a time when labor was scarce and shops were already full of orders. The first coal was unloaded on Aug. 13, after which time and before the close of navigation, approximately 300,000 tons were stored, ten months after the contract was let.

The plant was designed and built by the Dodge Coal Storage Co. of Philadelphia. The bulk of the machinery was manufactured for them by the Link-Belt Co., of Philadelphia and Chicago. The writer was in charge of the erection of the plant for the Dodge Co. from beginning to end of the work.

SOME DETAIL POINTS IN THE DESIGN AND CONSTRUCTION OF A RAILWAY VIADUCT.

By PHILIP AYLETT,* Assoc. M. Am. Soc. C. E.

In the construction of an extension of the Seaboard Air Line Ry. the writer had occasion to design and erect several long bridges and viaducts in which work his attention was directed to many matters of importance in such design and construction that may be of interest to the profession. These detail points are taken up in this article, using one of the aforementioned viaducts as an example with which to point the moral. The paper is more of a general nature than a specific description of one structure and the opinions and statements apply equally as well to other viaducts as to the one especially mentioned.

The viaduct under discussion carries a single track of the Atlanta-Birmingham extension of the Seaboard Air Line Ry. across the Chattahoochee River, about four miles from Atlanta, Ga., where the branch joins the main line of the system. At the site of this crossing the main channel of the stream during its normal stage is crescent shaped; somewhat similar, though of smaller extent, to that formed by the Mississippi River at New Orleans, La. The located line almost divides into halves that area bounded by the crescent bend on the west shore (Fig. 1). In the stream above the railway there are several islands, covered by trees which are submerged during flood. Several hundred feet above these islands Peachtree Creek enters the river, at which point the City of Atlanta has an intake for its water supply. The pumping station is near by and is surrounded by a heavy levee or embankment for protection at flood periods. Below the Seaboard crossing, approximately 1,200 ft., a public road bridge crosses the stream and still further down (about 1,000 ft.) the river is crossed by a bridge for the Nashville, Chattanooga and St. Louis Ry. The Seaboard viaduct consists of two 135 ft. 3-in. deck Pratt truss spans approached on one side by three 60-ft. and two 35-ft. plate girder spans and on the other side by one 46-ft., four 35-ft. and four 60-ft. plate girders spans. All piers and abutments are of mass concrete founded on rock.

PRELIMINARY SURVEYS.

After making the usual base-line measurements, triangulations, soundings, profiles, and securing high-water elevations, also the locations and dimensions of all existing structures in the vicinity, it is the writer's practice to traverse the banks of the stream above and below the proposed structure for several thousand feet, or more if necessary. In important cases, or where conditions demand it, this traverse is carried up and down both banks of the stream, and tied across at several points, thus affording a closed traverse and a check upon the work. The contour of the high-water plane is also established on adjacent high ground and the center-line profile is always extended to an intersection with same wherever they may be found on each shore. The high-water contours are established by level stakes, which are tied to the river traverse lines or to traverses run in for the purpose.

Such a survey is of high importance because of its direct bearing in establishing the directions of piers, length and character of channel spans and approaches, and also the course and directions taken by driftwood and debris during floods, thus contributing to the design of a structure suited not only to the requirements and conditions of the stream at its normal stages, but also to those obtaining at abnormal or flood stages, which are of far more importance. It is during periods of flood that damage to adjacent lands and the structure itself occur, and it is the designer's duty to know and meet flood requirements, thus eliminating maintenance expenditures and possible litigation.

Two of the most common blunders usually made in the design of structures over inland streams subject to overflow are in establishing the directions of the piers relatively to the current and in the length and character of the approaches over submerged lowlands. Piers adapted, both as to shape and direction to offer the least resistance to the stream at normal stages may be found entirely unadapted to the currents and drift of floods. It frequently happens that drift up to a certain elevation of the flood passes under the channel spans, while above this elevation it may take a short cut across the submerged low grounds, passing at one or more points under the approaches on one or both sides of the stream. Thus, much damage to the approaches is liable, if they are not designed with such conditions in view. The writer knows of several cases where grave blunders have been made, and litigation resulted, due to the sole fact that the structures and approaches were designed from the data furnished merely from a locating engineer's profile.

At Chattahoochee River a topographical survey of the stream and its vicinity, above and below, together with other data as outlined above, disclosed the fact that at flood, drift, instead of passing down the main channel of the stream, departed therefrom at the islands above and, taking a short cut over the submerged low-grounds enclosed by the crescent bend, again entered the stream at or near the public bridge. The direction of the public bridge piers, relatively to the channel, doubtless contributed largely to further deflection of the drift and debris below. The formation of the islands was due probably to

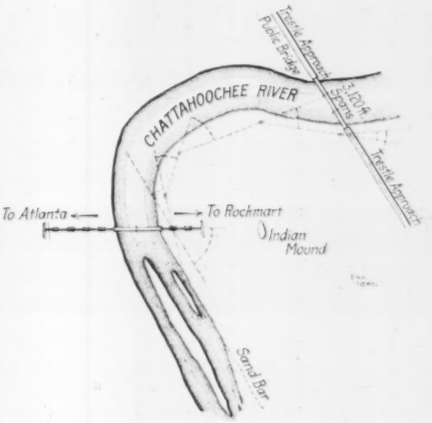


Fig. 1. Location Plan of Chattahoochee River Crossing.

eddies created by cross currents from Peachtree Creek. The located line crosses the stream nearly at right angles and is considered an excellent location at this point. The piers were built at right angles with the center line, and the west abutments located 250 ft. from Pier No. 11 of the channel spans with the steel viaduct on concrete pedestals intervening. No drift has been seen to pass west of this abutment. East of the river the viaduct approach is 426 ft. long, of a construction similar to that on the west side, except in the 46-ft. girder span over the water-works and clay-bank spur tracks. This girder span could not be given the standard depth of 6 ft. 10½ ins. from base of rail to bridge seat, as was done at the west abutment, a distance here of 4 ft. 7¾ ins. only being obtainable on account of under clearance.

MASONRY WORK.

At the east end the steel viaduct terminates on a concrete winged abutment, which retains the road-bed embankment behind it, and protects the water-works siding. On the west end a concrete abutment was also proposed and designed, but on account of trestlework being substituted for embankment, the wings of this abutment were (for the present) omitted until such time as their addition became necessary by filling in the trestle. Therefore only enough of this abutment as designed was built, as would provide merely a supporting pier for the girders. The stringers of the trestle are supported by this pier also, in notches provided in the back wall, thus avoiding the necessity for a frame-bent adjacent to the abutment for stringer support as is usually the case. Provision was made for bonding in thoroughly the wings, when built, by stepping and projecting embedded bars.

All pedestals and piers are constructed of concrete, mixed and proportioned in accordance with the standard specifications of the Seaboard

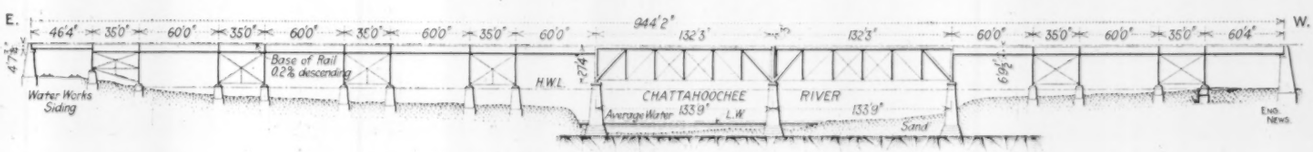


FIG. 2. THE CHATTAHOOCHEE RIVER VIADUCT OF THE SEABOARD AIR LINE RY.

*Formerly Bridge Engineer, Seaboard Air Line Ry. Now Terminal Engineer, Tidewater Ry., Portsmouth, Va.

Air Line Ry. The channel piers are founded upon solid rock, crib-cofferdams being used.

Copings of viaduct-pedestals and channel piers were fixed at elevations which would bring them within not less than two feet above extreme high water. It will be noted that the pedestals of bent No. 1 are carried up 4 ft. above the adjacent spur tracks in order to prevent accident to the columns from derailed engines or cars on these tracks. In the construction of concrete-pedestals for viaducts, or, indeed for any concrete structures of small dimensions and volume, it is the writer's practice to establish in the office and show on the masonry layout the neat line elevations of every pedestal as well as the coping elevations. By doing this, full details, dimensions, batters, heights, etc., can be given on the masonry layout for each pedestal and thus nothing left for judgment or computation in the field; at least above ground. Lengths, sizes and spacing of all anchor-bolts are also given.

MONOLITHIC CONSTRUCTION.—Thus with complete information covering every pedestal above neat line, given on the masonry layout, the forms can be completed to coping offset; and the coping form and anchor-bolt templates made ready for immediate use.

This course will insure continuous work and monolithic construction, from neat line to top of coping, there being no occasion for interruption of the work between these points. It has been observed that a serious blunder is usually made by stopping the concrete work at the bottom of anchor-bolts and delaying it there until the bolts are set in position, which usually takes long enough to allow the setting up of deposited concrete. Often the work is left in this state for days. This results always in a joint or seam in the pedestal below anchor-bolts. There being little or no bond between the old and new concrete at this point, uplift can only be counteracted by that mass of the pedestal embedding the bolts above this joint. This mass being generally about 4 ins. shorter than the bolts themselves. Furthermore, the section of the pedestal at this joint is still further weakened on account of the location of the anchor-plates, in the plane of these joints, and thus depriving the pedestal section of an area equal to the combined areas of the plates. There are usually four plates, from 6 to 8 ins. square each; consequently the pedestals are robbed of from 144 to 256 sq. ins. of their sectional area at a point which has already been weakened by non-continuous concrete work.

The writer has seen viaduct pedestals severed in twain immediately below the anchor-bolts by uplift and vibrations from the moving loads solely from above causes. In one instance the upper portion of the pedestal containing the embedded anchor-bolts slipped forward on the lower portion approximately ½-in. or more. This backward and forward movement had continued until the concrete surfaces at the fractured section had begun to wear smooth from this grinding and polishing action under the movement of trains. The importance of continuous concrete work in pedestal construction being so obvious, field engineers, inspectors and all concerned are given special instructions, and in all cases it is the writer's practice to place conspicuously on the masonry layout a note as follows or similar thereto:

> All pedestals must be carried up to completion from neat line to top of coping, without interruption, so that the completed structure will be one solid monolithic mass.

Further than this, in order to avoid defective construction, as described above, the writer has specified in recent structures anchor-bolts of different lengths, also "boulder bond." Both of these methods have proven to be satisfactory.

It is sometimes necessary in pedestal construction, in order to obtain a monolith of sufficient depth from the top to counteract uplift, vibrations, etc., to resort to one of the following devices or a combination of them: (1) lowered neat lines; (2) increased dimensions; (3) continuous concrete work even at neat lines; (4) "boulder bond"; (5) increased lengths of anchor-bolts, these acting as reinforcing or bonding bars. No stop in the work should be allowed at neat lines unless the mass above is sufficient in weight and dimensions. If there is uplift at all, or even if there is absolutely none—the mass of the pedestal included within the lengths of anchor-bolts cannot be sufficient—if the anchors are of customary lengths and the pedestals of economic dimensions.

It appears from observation on various railways of a large number of pedestals during construction that all of them are made up of never less than two monoliths, one above and one below neat line, and that 90% or more are composed of three monoliths, one below neat line and two above. The dividing line between the two monoliths above ground is at the plane of the anchor-plates or the thickness of the anchor-bolt heads below the plates, where the work was delayed in setting up and lining anchor-bolts. The writer has found by actual uplift tests (upon full size pedestals and columns) that viaduct columns anchored with ordinary (not ragged) stone-bolts only 12 ins. in length, leaded and sulphured (or simply cemented) in holes drilled into top of pedestal after erection, afford a far stronger, safer and more satisfactory job than do tower-columns anchored by 4-ft. bolts 1¼ ins. in diameter (with anchor-plates 6 × ½ × 6 ins.) embedded in pedestals, built without regard to monolithic construction, or other precautions, as above set forth.

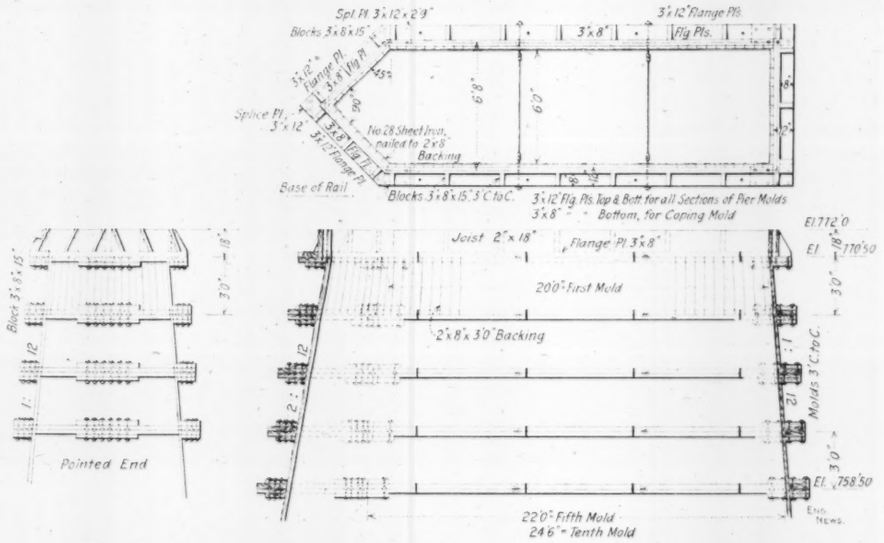


FIG. 3. FORMS FOR CONCRETE PEDESTALS ON THE CHATTAHOOCHEE VIADUCT.

At Chattahoochee River the pedestals were monoliths. After completion the pedestals and piers were floated down and washed with cement grout and the 8 × 8-in. steel cut-water angles on the channel piers were given two coats of black paint, as was also the entire superstructure.

FORMS.—The planking of pedestal and pier forms was undressed and lined inside with No. 28 sheet iron. This not only secured a smooth outside finish but hastened delivery of lumber for forms inasmuch as no dressing was necessary at the mills. Special forms for the river piers were designed with a view to rapidity of erection and their repeated use, important considerations on account of the frequent and rapid rises of this stream.

The essential feature of these forms consists in constructing the entire form on shore in advance in 3-ft. sections from neat line up, placed one upon the other as the concrete advances. (Fig. 2.) All that was necessary to connect adjacent sections was to bolt the 3 × 12-in. flange plates (or pieces) through open holes provided in same. The matching of these holes in the flanges brought the interior faces of the form sections in true continuity throughout.

Interior faces of forms were lined with No. 28 sheet iron. Butt joints were used exclusively in the lining metal. Sections of forms were conveyed from shore to piers by cableway, and let down in place on the section previously placed and concreted; holes in flanges matched and bolted, and thus another 3-ft. section was made ready for concrete. This operation of adding new sections required about ten minutes only. Thus the concrete is continuous, and piers are secured which are practically solid monoliths.

The top of each form section, immediately after placing, was brought to the computed elevation, as given on the detail drawing, by an engineer's wye level from the shore or another pier.

Tie rods ¾-in. in diameter with a threaded sleeve near each of its ends are shown; these prevent bulging of forms by the wet concrete. Those portions of the tie rods between the sleeves and forms are unscrewed from sleeves and removed, thus leaving no rods projecting in the face. Further description is unnecessary—the drawings and notes thereon being full and explicit.

STEEL SUPERSTRUCTURE.

In the towers where the 35-ft. girders are placed vertical tie members were provided between the centers of the bottom horizontal longitudinal struts and the intersections of the longitudinal cross-bracing as shown. The writer has never shared the opinion of some engineers that these vertical members, because they are subjected to no stress, are unnecessary and add useless expense. In the light of one experience, some years ago, these members are considered important in viaducts forming approaches over low grounds subject to overflow, and crossing the path of floating brush and debris.

In the experience referred to the conditions were these: a long steel viaduct formed the approach to the channel spans of a single-track railway bridge over a southern stream, which was subject to high freshets, submerging a vast area of low-lands. During the high stages of the flood the bulk of the drift left the channel at a point above the crossing, and taking a short cut across the low-lands passed under the viaduct approach. A large tree, with projecting branches, was caught and held in its passage by the bottom longitudinal strut of one of the towers and, thus obstructing other drift, caused the formation of a high and dense "hammock," which, aided by the rising flood, soon mounted the column strut located about 4 ft. above the water surface. The great weight of this wet mass, added to the force of the water and impact from drifting logs, broke the strut. The floating mass thus freed passed on, and coming in contact with the down-stream strut of the

ame tower also, broke it instantly. A vertical member connecting the centers of these struts to the longitudinal bracing would have doubtless enabled them to have withstood this flood, certainly until daylight.

In renewals of existing viaducts upon the Seaboard System it is customary to adopt a uniform depth between base of rail and top of columns common to both tower and intermediate spans. This depth for viaducts upon the Birmingham Extension was 6 ft. 9½ ins.

Two 7 × 5-16-in. plates, bolted in position through slotted holes, were used to connect adjacent ends of girders over columns. These plates add much to the appearance of the viaduct by covering the clearance spaces over columns between ends of adjacent spans, thus producing a continuous and unbroken girder line of uniform depth from end to end. These plates also assist in maintenance of alinement, and increase rigidity and are constructed so that expansion is not interfered with. In connections, over columns, between girders of different depths it has been observed that unsatisfactory details as to both strength and appearance is usually the case in railway and highway viaducts.

Erection commenced at the east abutment, near which a derrick was raised for unloading steel from cars on the spur tracks. On account of the embankment not having been completed behind the abutment the viaduct was erected from the ground by a gin-pole. A temporary track was laid from the spur tracks to the river a few feet distant and parallel to the viaduct. Material was taken from push cars on this track by the gin-pole. The 60-ft. girder adjacent to the truss span was not erected until both channel spans were completed and all the steel for the viaduct on the west bank had been transported across the stream.

The procedure after completing the erection to bent 8 was as follows: the 60-ft. girder between bents 8 and 9 being omitted temporarily, the gin-pole was located at this point near pier 9 on the center line. A track was laid through the first truss span upon ties resting upon its bottom chords, and the material for the second span was supplied over this track. At completion of the second channel span the bottom chord track was extended over same for transporting the viaduct material, which was subsequently erected.

The assumed live loading used in this structures was Cooper's "E 50," with an assumed dead loading as follows: 35-ft. spans, 925 lbs. per lin. ft.; 60-ft. spans, 1,150 lbs. per lin. ft.; truss spans, 2,100 lbs. per lin. ft. Fixed ends of truss spans were located on piers 9 and 11, thus bringing the expansion ends of both spans upon pier 10.

Between the vertical end posts solid web plate girders or floorbeams are provided, acting as struts, and to these the adjacent 60-ft girder spans of viaduct are riveted. Special care was also taken to secure satisfactory connections here. All steel work, quality of material, allowable stresses, etc., was in accordance with S. A. L. Ry. specifications of 1902.

ORGANIZATION.—In conclusion, the writer acknowledges his thanks and indebtedness to the superstructure contractors, The American Bridge Co., for their cheerful and energetic cooperation in securing a high standard in designs, material and workmanship in this and many other structures erected under the writer's supervision; also to Mr. W. C. Watson, Assistant Bridge Engineer, for his valuable assistance in drawings and design; to Mr. C. T. Peed, draftsman, and to Mr. Thos. B. Cox, Chief Inspector of Erection, for their constant vigilance and care.

During the construction of this work, Mr. W. W. Gwathmey was Chief Engineer S. A. L. Ry., Major D. B. Dunn, Division Engineer, and Mr. S. P. Daniels, Resident Engineer. Credit is due these gentlemen and to the contractor for substructure, Mr. B. M. Hardaway, for the extreme accuracy and efficient handling of this work throughout and the highly satisfactory results achieved.

THE MOISTURE IN THE ATMOSPHERE AND ITS EFFECT ON THE OPERATION OF COMPRESSED AIR MACHINERY, ESPECIALLY AIR BRAKE, MULTIPLE-UNIT TRAIN CONTROL AND TRAIN SIGNAL SYSTEMS.*

By H. M.-PREVOST MURPHY.†

Ever since the introduction of compressed air into the railway and commercial fields, much imperfect operation and many failures have resulted from the presence of condensed moisture in vital parts of the apparatus used. Long practical experience and careful, scientific investigation have, however, demonstrated that all difficulties arising from this source may be reduced to comparative insignificance, if not entirely eliminated, by properly installing the various devices concerned. The objects of this article are to point out the physical laws involved in the subject, to explain the most approved methods of securing "dry air" for use in any system, and to establish a correct method for determining the amount of moisture that is deposited by compressed air under various operating conditions.

Although the troubles resulting from "wet air" are of much consequence in stationary work, where complicated pneumatic machines are used, it is seldom that any very serious accidents occur in this field; loss of time and broken tools usually being the extent of the damage done. It is in the operation of modern railways, particularly electric systems, where the problem assumes a most important nature. This will be readily appreciated when it is remembered that on a large number of such roads the block signals, interlocking switches, multiple-unit control equipments and automatic brakes are all operated by compressed air.

Of course, the evil effects of excess moisture, if permitted to enter any of the systems referred to, are readily imagined if indeed not already familiar to the reader. In warm climates, where freezing weather is never experienced, any water

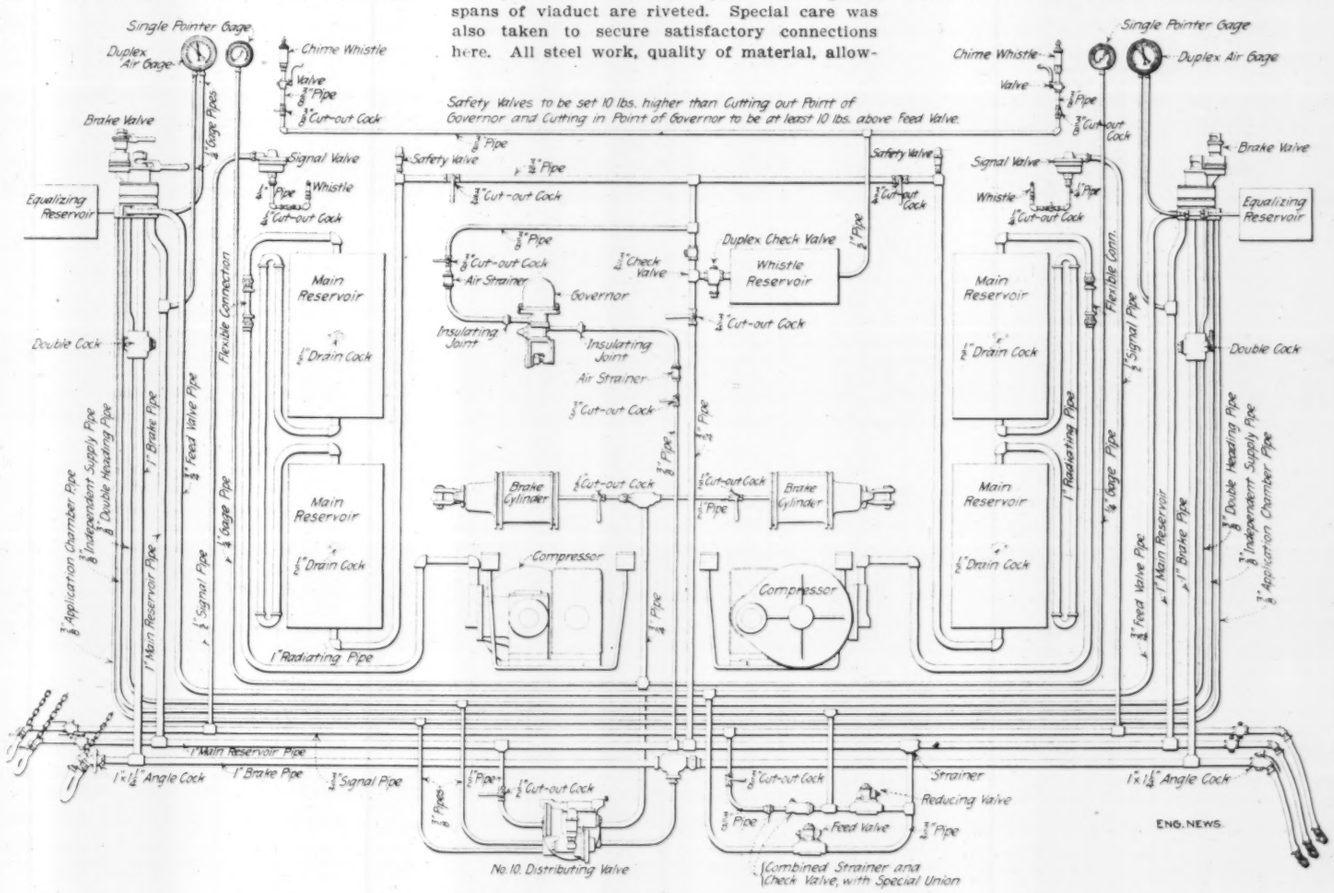


FIG. 1. DIAGRAMMATIC ARRANGEMENT OF A WESTINGHOUSE AIR-BRAKE EQUIPMENT FOR ELECTRIC LOCOMOTIVE.

*Copyright, 1908, by Engineering News Publishing Co.

†Mechanical Engineer, Westinghouse Air Brake Co., Pittsburg, Pa.

passing through and deposited in the various valves and passages is not a positive source of danger, although it may cause extremely sluggish and unsatisfactory operation, but it will inevitably produce a much more rapid deterioration of the apparatus than would otherwise be the case. On the other hand, in latitudes where freezing does occur for even short periods of time, any water which is deposited in these systems is not only liable to burst pipes and valves, but also to so obstruct the ports and passages of the various devices and even to so entirely block the action of the moving parts, that failures from this source are, unfortunately, of too frequent occurrence during the winter months.

In order to clearly understand the situation and to obtain a useful knowledge of the methods employed in practice to obviate the difficulties experienced from the presence of the moisture in the atmosphere, it will be necessary to first investigate the simple unvarying physical laws which govern the case. These laws may be stated as follows:

(1) Atmospheric air always contains some moisture, which it absorbs from rivers, creeks, rainfall, etc.

(2) The amount of moisture present in the atmosphere depends on local conditions and on the weather.

(3) The maximum amount of moisture that pure air can contain depends only on its temperature and pressure, and has an unvarying value for each condition.

(4) The higher the temperature of the air, the greater is the amount of moisture that it can contain.

(5) The higher the pressure of the air, the smaller is the amount of moisture that it can contain.

(6) When air is compressed, its temperature rapidly rises to a high point, which depends on the design and speed of the compressor and the delivery pressure worked against.

(7) The rise of temperature due to the compression of the air, in all cases found in practice, far more than offsets the opposite effect of the rise of pressure on the moisture carrying capacity of the air.

As a result of these laws, it is easy to see how water is deposited by compressed air as it passes from the pump to the various portions of the system. Suppose that a certain amount of atmospheric air enters a compressor and that this air is at the saturation point, that is that it contains all the moisture possible at the existing outside temperature and pressure. Then as this air is compressed as stated in law (7), its moisture carrying capacity very rapidly increases, for the rise of temperature more than offsets the opposite effect of the rise of pressure, consequently all the moisture in the air is still retained by it and passes with it into the main, or storage, reservoir and its connecting pipes. Now if this air is permitted to pass from here into the various parts of the system before being cooled to the outside temperature, it will; of course, carry more moisture with it than it is capable of holding in suspension when the temperature finally drops to the normal point, and this excess quantity will then be deposited, because, the pressure being high, the air cannot hold as much moisture as it did at the same temperature and only atmospheric pressure (law 5).

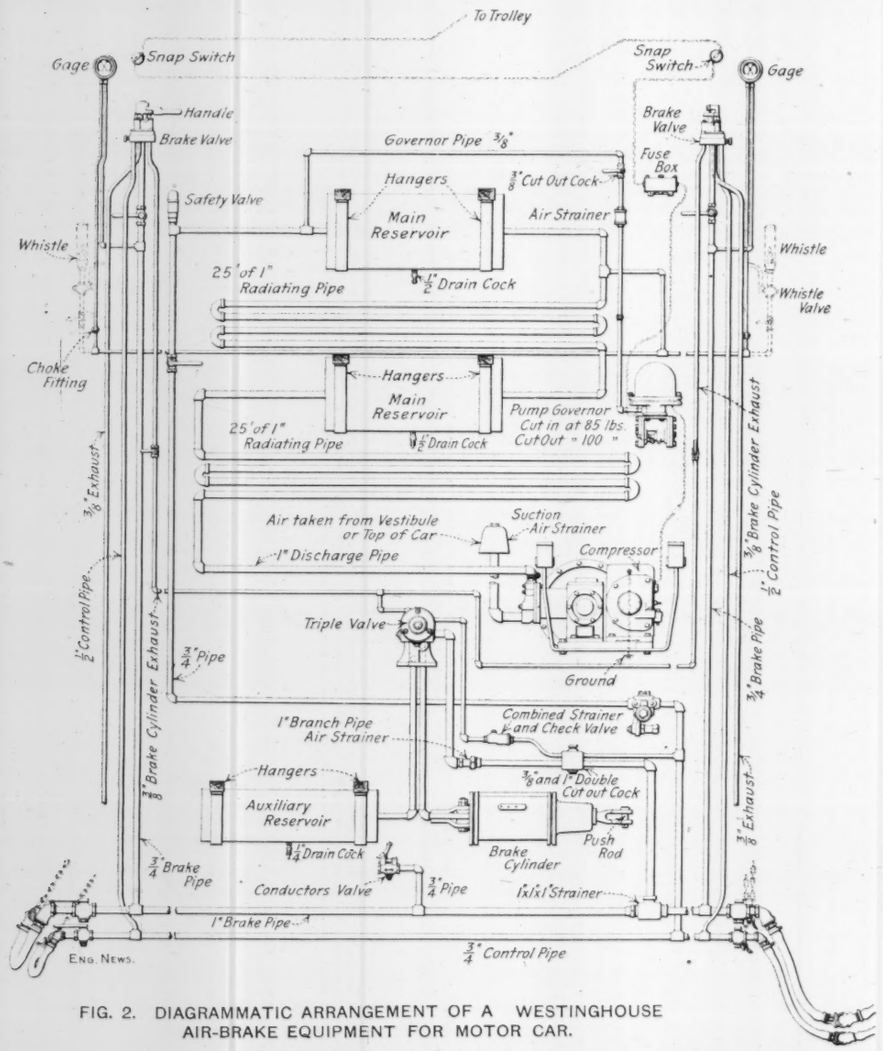


FIG. 2. DIAGRAMMATIC ARRANGEMENT OF A WESTINGHOUSE AIR-BRAKE EQUIPMENT FOR MOTOR CAR.

Now, as will be readily seen, in order to reduce to a minimum the evil effects of this water, which is bound to appear in any compressed air system under average weather conditions, it is most desirable to cause the air to deposit all of its excess moisture in the main reservoirs, from which it may be easily removed by the drain cocks which should always be provided for that purpose. In order to accomplish this completely, it is merely necessary to *cool the air to the outside temperature before it leaves these reservoirs.* This may easily be done by using a sufficiently long air discharge or radiating pipe between the pump and the main reservoirs which should be of large capacity not only to provide for an ample storage of air but also in order to allow the compressed air to remain in them for a length of time sufficient to permit the superfluous moisture to be completely deposited and to insure a liberal supply of cold air at all times. The use of pressure reducing valves between the main reservoirs and the rest of the system is sometimes considered of benefit in securing "dry air," but as such devices simply cause some of the moisture to be deposited in the pipes near at hand (not in the main reservoirs) instead of in the more remote parts of the system, the merits of this method are extremely doubtful and it should never be resorted to unless drain cups are placed in the pipes concerned, for excess water vapor once allowed to pass from the main reservoirs will surely cause ultimate trouble unless it be properly trapped and regularly drained off.

In stationary work where the air is sometimes reheated before being used, in order to increase the efficiency of the devices operated by it, no trouble ought ever to be experienced from the moisture, but in all other installations, including those on railways, long radiating pipes should always be employed. Of course it is true that even if the compressed air be cooled to the existing outside temperature, before leaving the main reservoir, some moisture may be deposited in the rest of the system, if a drop of the outside temperature occurs, but the amount of water thus produced must obviously be very small, and appears merely as little beads on the interior walls of the various devices. It is seldom that any trouble is experienced from this source alone. Moreover, although compressed air may be properly dried before leaving the main reservoirs, some moisture may be temporarily deposited when the air is subsequently expanded to lower pressures, as the moisture carrying capacity of the air is usually affected more by the drop in temperature, resulting from the expansion, than by the drop in pressure, but when the air again attains the outside temperature, the moisture thus deposited will be re-absorbed if it is freely exposed to the compressed air.

In order to show how installations should be made so as to secure "dry air" for use in any system, piping diagrams of modern Westinghouse air-brake equipments for street railway and interurban cars and electric locomotives are illustrated by Figs. 1 and 2, in both of which the radiating pipe is clearly indicated. For stationary plants, such as automatic switch and signal stations, similar radiating systems should be employed in addition to which water-jacketed compressors should be used whenever possible not only to secure a high mechanical efficiency but also to aid the radiating pipes in the performance of their duty. As a general proposition in railway work, 50 to 70 ft. of this pipe is considered the correct amount, and, when used, no trouble whatever should be experienced with wet air, if the reservoirs are carefully drained every day or, in moist climates, after each long run.

In order to determine exactly what percentage of moisture pure air can contain at various pressures and temperatures, to ascertain how low the "relative humidity" of the atmosphere must be in order that no water will be deposited in any part of a compressed air system and also to find to what temperature air drawn from a saturated atmosphere must be cooled in order to cause the deposition of moisture to commence, the following discussion is necessary, as no cor-

rect method has heretofore been published to cover the situation.

In order to obtain the desired information, it is only necessary to remember a well-known physical law which covers the case of most mixed gases with great exactitude, for water vapor is merely a gas. This law is known as "Dalton's Law of Gaseous Pressures," and may be stated as follows.

Every portion of a mass of gas enclosed in a vessel contributes to the pressure against the sides of the vessel the same amount that it would have exerted by itself had no other gas been present.

In other words, the total pressure exerted against the interior of a vessel by a given quantity of a mixed gas enclosed in it is the sum of the pressures which each of the component gases would exert separately if it were enclosed alone in a vessel of the same bulk, at the same temperature.

This law applies to mixtures of pure air and saturated water vapor, and in order to determine the maximum weight of moisture that can be held in suspension by one pound of pure air at any temperature and pressure it is merely necessary to proceed as outlined in what follows.

Letting p_2 represent the absolute pressure in lbs. per sq. in., and t the temperature Fahrenheit, the weight in lbs. of 1 cu. ft. of pure air is known to be equal to:

$$2.698192 \times \frac{p_2}{459.2 + t}.$$

Also letting N equal the volume in cubic feet of one pound of pure air at the temperature, t, and pressure, p_2, there results the equation:

$$1 = N \times 2.698192 \times \frac{p_2}{459.2 + t} \quad \ldots\ldots\text{(Equation 1)}$$

Now w, the weight in lbs. of 1 cu. ft. of saturated steam (or water vapor) at the temperature, t, and corresponding absolute pressure, p_1, in lbs. per sq. in., has been shown by the author to be accurately expressed, in accordance with the average values given by the most reliable authorities, by the following equation, for all conditions:

$$w = \frac{p_1}{459.2 + t}\left(1.6494 + \frac{0.248\ t}{850 - t}\right)$$

and by letting W represent the weight of N cubic feet of saturated steam at the temperature, t, and pressure, p_1, there results the equation:

$$W = \frac{N\ p_1}{459.2 + t}\left(1.6494 + \frac{0.248\ t}{850 - t}\right) \ldots\text{(Equation 2)}$$

By taking the N cubic feet of pure air at pressure, p_2, and the N cubic feet of saturated steam at the pressure, p_1, and forcing them both into one vessel of volume, N, keeping the temperature constant at the value, t, the resulting pressure, by Dalton's law, will be $p_2 + p_1$, which may be placed equal to p, thus:

$$p = p_2 + p_1 \ldots\ldots\ldots\ldots\text{(Equation 3).}$$

W will, of course, represent the maximum weight of water vapor that 1 lb. of pure air can contain under the given conditions of pressure and temperature, as the steam considered is at the saturation point. To obtain the desired formula

TABLE I.—A TABLE WITH FORMULAS GIVING THE WEIGHTS, IN LBS., OF 1 CU. FT. OF DRY AIR, OF 1 CU. FT. OF SATURATED STEAM OR WATER VAPOR AND THE MAXIMUM WEIGHT OF WATER VAPOR THAT 1 LB. OF PURE AIR CAN CARRY AT ANY PRESSURE AND TEMPERATURE. (Copyright, 1908, by H. M.-Prevost Murphy.)

The Values K and H Being Given in the Table for Various Temperatures, t, in Fahrenheit Degrees, the Formulas Are:

Weight of 1 Cu. Ft. Saturated Steam $= \dfrac{1.325271\ K\ H}{459.2 + t}$ (Exactly).

Weight of 1 Cu. Ft. Saturated Steam $= \dfrac{1.3253\ K\ H}{459 + t}$ (Approximately).

H Being Equal to 2.036 × (Gage Pressure + Atmos. Pres., in Lbs. per Sq. Inch).
H, K and t Having Corresponding Values as Given in Table

Weight of 1 Cu. Ft. Pure Dry Air $= \dfrac{1.325271\ M}{459.2 + t}$ (Exactly).

Weight of 1 Cu. Ft. Pure Dry Air $= \dfrac{1.3253\ M}{459 + t}$ (Approximately).

Weight of 1 Cu. Ft. Pure Dry Air $= \dfrac{2.698192\ P}{459.2 + t}$ (Exactly).

Weight of 1 Cu. Ft. Pure Dry Air $= \dfrac{2.7\ P}{459 + t}$ (Approximately).

M Being the Absolute Pressure Measured in Inches of Mercury;
P Being the Absolute Pressure Measured in Lbs. per Sq. Inch.

Letting W = the Maximum Wt., in Lbs., Water Vapor, that 1 Pound of Pure Air Can Contain, when the Temperature of the Mixture is t, and the Total, or Observed, Absolute Pressure in Lbs. per Sq. Inch is P, the Value of W, is:

$$W = \frac{K\ H}{2.036\ P - H} \text{ (Exactly).}$$

The Values of K and H Corresponding to the Existing Temperature Being Given by the Table.

For Any Temperature the Value of K (the Ratio of the Wt. of a Volume of Saturated Stream to an Equal Volume of Pure Dry Air at the Same Temperature and Pressure) May Be Accurately Computed by the Following Formula:

$$K = 0.6113 + \frac{0.092\ t}{850 - t} \text{ (Exactly).}$$

Note.—The Results Obtained by the Use of Any of the Above Formulas Agree Exactly with the Average Data for Air and Steam Weights as Given by the Most Reliable Authorities and Careful Experiments, for All Pressures and Temperatures; the Value of K Being Correct for All Temperatures up to the Critical Steam Temperature of 689° F.

TABLE GIVING THE VALUES OF "K" AND "H" CORRESPONDING TO EACH FAHRENHEIT DEGREE OF TEMPERATURE FROM 30° BELOW TO 434° ABOVE ZERO.

Temperature Degrees Fahrenheit, t	Values of K	Values of H	Temperature Degrees Fahrenheit, t	Values of K	Values of H	Temperature Degrees Fahrenheit, t	Values of K	Values of H	Temperature Degrees Fahrenheit, t	Values of K	Values of H	Temperature Degrees Fahrenheit, t	Values of K	Values of H
-30	.6082	.0099	17	.6132	.0941	64	.6188	.3962	111	.6251	2.654	158	.6323	9.177
-29	.6083	.0105	18	.6133	.0983	65	.6189	.6175	112	.6253	2.731	159	.6325	9.400
-28	.6084	.0111	19	.6134	.1028	66	.6190	.6393	113	.6255	2.811	160	.6326	9.628
-27	.6085	.0117	20	.6135	.1074	67	.6192	.6617	114	.6256	2.892	161	.6328	9.860
-26	.6086	.0123	21	.6136	.1122	68	.6193	.6848	115	.6257	2.976	162	.6330	10.10
-25	.6087	.0130	22	.6137	.1172	69	.6194	.7086	116	.6258	3.061	163	.6331	10.34
-24	.6088	.0137	23	.6139	.1224	70	.6196	.7332	117	.6260	3.149	164	.6333	10.59
-23	.6089	.0144	24	.6140	.1279	71	.6197	.7585	118	.6261	3.239	165	.6335	10.84
-22	.6090	.0152	25	.6141	.1336	72	.6198	.7846	119	.6263	3.331	166	.6336	11.10
-21	.6091	.0160	26	.6142	.1396	73	.6199	.8114	120	.6264	3.425	167	.6338	11.36
-20	.6092	.0168	27	.6143	.1458	74	.6201	.8391	121	.6266	3.522	168	.6340	11.63
-19	.6093	.0177	28	.6144	.1523	75	.6202	.8676	122	.6267	3.621	169	.6341	11.90
-18	.6094	.0186	29	.6146	.1590	76	.6203	.8969	123	.6269	3.722	170	.6343	12.18
-17	.6095	.0196	30	.6147	.1661	77	.6204	.9271	124	.6270	3.826	171	.6345	12.46
-16	.6096	.0206	31	.6148	.1734	78	.6206	.9585	125	.6272	3.933	172	.6346	12.75
-15	.6097	.0216	32	.6149	.1811	79	.6207	.9906	126	.6273	4.042	173	.6349	13.04
-14	.6098	.0227	33	.6150	.1884	80	.6209	1.024	127	.6276	4.153	174	.6350	13.34
-13	.6099	.0238	34	.6151	.1960	81	.6210	1.057	128	.6276	4.267	175	.6352	13.65
-12	.6100	.0250	35	.6153	.2039	82	.6211	1.092	129	.6278	4.384	176	.6353	13.96
-11	.6101	.0262	36	.6154	.2120	83	.6213	1.128	130	.6279	4.503	177	.6355	14.28
-10	.6102	.0275	37	.6155	.2205	84	.6214	1.165	131	.6281	4.625	178	.6357	14.60
-9	.6103	.0289	38	.6156	.2892	85	.6215	1.203	132	.6282	4.750	179	.6359	14.92
-8	.6104	.0303	39	.6157	.2382	86	.6217	1.242	133	.6284	4.877	180	.6360	15.27
-7	.6103	.0317	40	.6158	.2476	87	.6218	1.282	134	.6285	5.008	181	.6362	15.62
-6	.6107	.0332	41	.6160	.2572	88	.6219	1.324	135	.6287	5.142	182	.6364	15.97
-5	.6108	.0348	42	.6161	.2673	89	.6221	1.366	136	.6288	5.280	183	.6365	16.32
-4	.6109	.0365	43	.6162	.2776	90	.6222	1.410	137	.6290	5.420	184	.6367	16.68
-3	.6110	.0382	44	.6163	.2883	91	.6223	1.455	138	.6291	5.563	185	.6369	17.05
-2	.6111	.0400	45	.6164	.2994	92	.6225	1.501	139	.6293	5.709	186	.6371	17.43
-1	.6112	.0419	46	.6166	.3109	93	.6226	1.548	140	.6294	5.859	187	.6373	17.81
0	.6113	.0439	47	.6167	.3227	94	.6227	1.597	141	.6296	6.011	188	.6374	18.20
+1	.6114	.0459	48	.6168	.3350	95	.6229	1.647	142	.6298	6.167	189	.6376	18.59
2	.6115	.0481	49	.6169	.3477	96	.6230	1.698	143	.6299	6.327	190	.6377	19.00
3	.6116	.0503	50	.6170	.3608	97	.6232	1.751	144	.6301	6.490	191	.6380	19.41
4	.6117	.0526	51	.6172	.3743	98	.6233	1.805	145	.6302	6.656	192	.6381	19.83
5	.6118	.0551	52	.6173	.3883	99	.6234	1.861	146	.6304	6.827	193	.6383	20.25
6	.6120	.0576	53	.6174	.4027	100	.6236	1.918	147	.6305	7.001	194	.6385	20.69
7	.6121	.0603	54	.6175	.4176	101	.6237	1.976	148	.6307	7.178	195	.6387	21.13
8	.6122	.0630	55	.6177	.4331	102	.6238	2.036	149	.6309	7.359	196	.6389	21.58
9	.6123	.0659	56	.6178	.4490	103	.6240	2.098	150	.6310	7.545	197	.6391	22.04
10	.6124	.0690	57	.6179	.4655	104	.6241	2.161	151	.6312	7.736	198	.6393	22.50
11	.6125	.0722	58	.6180	.4824	105	.6243	2.226	152	.6313	7.929	199	.6394	22.97
12	.6126	.0754	59	.6182	.4999	106	.6244	2.294	153	.6315	8.127	200	.6396	23.46
13	.6127	.0789	60	.6183	.5180	107	.6246	2.362	154	.6317	8.328	201	.6397	23.94
14	.6128	.0824	61	.6184	.5367	108	.6247	2.432	155	.6318	8.534	202	.6400	24.44
15	.6130	.0862	62	.6185	.5559	109	.6248	2.504	156	.6320	8.744	203	.6402	24.95
16	.6131	.0900	63	.6187	.5758	110	.6250	2.578	157	.6322	8.958	204	.6404	25.47

Temperature Degrees Fahrenheit, t	Values of K	Values of H	Temperature Degrees Fahrenheit, t	Values of K	Values of H	Temperature Degrees Fahrenheit, t	Values of K	Values of H	Temperature Degrees Fahrenheit, t	Values of K	Values of H	Temperature Degrees Fahrenheit, t	Values of K	Values of H
205	.6405	25.99	251	.6499	61.89	297	.6607	130.8	343	.6736	250.9	389	.6890	444.4
206	.6407	26.53	252	.6501	62.97	298	.6610	132.8	344	.6739	254.2	390	.6893	449.6
207	.6409	27.07	253	.6503	64.08	299	.6612	134.8	345	.6741	257.6	391	.6897	454.9
208	.6411	27.62	254	.6505	65.21	300	.6615	136.8	346	.6745	261.0	392	.6901	460.2
209	.6413	28.18	255	.6508	66.34	301	.6617	138.9	347	.6749	264.5	393	.6905	465.6
210	.6415	28.75	256	.6510	67.49	302	.6620	141.0	348	.6751	268.0	394	.6908	470.9
211	.6417	29.33	257	.6512	68.66	303	.6623	143.1	349	.6754	271.5	395	.6911	476.4
212	.6419	29.92	258	.6514	69.85	304	.6625	145.3	350	.6757	275.0	396	.6915	481.9
213	.6421	30.53	259	.6516	71.05	305	.6628	147.4	351	.6760	278.6	397	.6919	487.4
214	.6423	31.14	260	.6518	72.26	306	.6631	149.6	352	.6763	282.2	398	.6923	493.0
215	.6424	31.76	261	.6521	73.50	307	.6633	151.8	353	.6767	285.9	399	.6927	498.7
216	.6426	32.38	262	.6523	74.75	308	.6636	154.1	354	.6770	289.6	400	.6931	504.4
217	.6428	33.02	263	.6525	76.02	309	.6639	156.3	355	.6773	293.3	401	.6935	510.1
218	.6430	33.67	264	.6528	77.30	310	.6641	158.7	356	.6776	297.1	402	.6939	515.9
219	.6432	34.33	265	.6530	78.61	311	.6644	161.0	357	.6780	300.9	403	.6943	521.7
220	.6434	35.01	266	.6532	79.93	312	.6647	163.3	358	.6783	304.8	404	.6947	527.6
221	.6436	35.69	267	.6534	81.27	313	.6650	165.7	359	.6786	308.7	405	.6951	533.5
222	.6438	36.38	268	.6537	82.62	314	.6652	168.1	360	.6789	312.6	406	.6956	539.5
223	.6440	37.08	269	.6539	84.00	315	.6655	170.5	361	.6792	316.6	407	.6958	545.6
224	.6442	37.80	270	.6541	85.39	316	.6658	173.0	362	.6796	320.6	408	.6962	551.6
225	.6444	38.53	271	.6543	86.83	317	.6661	175.5	363	.6799	324.6	409	.6966	557.8
226	.6446	39.27	272	.6546	88.26	318	.6663	178.0	364	.6803	328.7	410	.6970	564.0
227	.6448	40.02	273	.6548	89.71	319	.6666	180.6	365	.6806	332.8	411	.6975	570.2
228	.6451	40.78	274	.6551	91.18	320	.6669	183.1	366	.6809	337.0	412	.6979	576.5
229	.6453	41.56	275	.6553	92.67	321	.6671	185.7	367	.6813	341.2	413	.6983	582.8
230	.6455	42.34	276	.6555	94.18	322	.6674	188.3	368	.6816	345.4	414	.6987	589.3
231	.6457	43.14	277	.6558	95.71	323	.6677	191.0	369	.6820	349.7	415	.6991	595.7
232	.6458	43.95	278	.6560	97.26	324	.6680	193.7	370	.6822	354.0	416	.6995	602.2
233	.6460	44.77	279	.6563	98.83	325	.6683	196.5	371	.6826	358.4	417	.6999	608.8
234	.6463	45.61	280	.6565	100.4	326	.6686	199.2	372	.6829	362.8	418	.7003	615.4
235	.6465	46.46	281	.6568	102.0	327	.6689	202.0	373	.6832	367.3	419	.7007	622.1
236	.6467	47.32	282	.6570	103.7	328	.6691	204.8	374	.6836	371.8	420	.7012	628.8
237	.6469	48.19	283	.6572	105.3	329	.6694	207.7	375	.6839	376.3	421	.7016	635.6
238	.6471	49.08	284	.6575	107.0	330	.6697	210.5	376	.6843	380.9	422	.7021	642.5
239	.6473	49.98	285	.6577	108.7	331	.6700	213.5	377	.6847	385.5	423	.7026	649.4
240	.6475	50.89	286	.6580	110.4	332	.6703	216.4	378	.6850	390.2	424	.7029	656.3
241	.6477	51.83	287	.6582	112.1	333	.6707	219.4	379	.6853	394.9	425	.7033	663.3
242	.6479	52.77	288	.6584	113.9	334	.6709	222.4	380	.6857	399.6	426	.7037	670.4
243	.6481	53.72	289	.6587	115.8	335	.6712	225.4	381	.6861	404.3	427	.7042	677.5
244	.6484	54.69	290	.6590	117.5	336	.6715	228.5	382	.6865	409.3	428	.7046	684.7
245	.6486	55.68	291	.6592	119.3	337	.6717	231.6	383	.6868	414.2	429	.7051	691.9
246	.6488	56.67	292	.6594	121.2	338	.6721	234.7	384	.6871	419.1	430	.7055	699.2
247	.6490	57.69	293	.6597	123.1	339	.6724	237.9	385	.6875	424.1	431	.7059	706.5
248	.6492	58.71	294	.6600	125.0	340	.6727	241.1	386	.6879	429.1	432	.7064	713.9
249	.6494	59.76	295	.6602	126.9	341	.6730	244.3	387	.6882	434.2	433	.7068	721.4
250	.6496	60.81	296	.6604	128.8	342	.6733	247.6	388	.6886	439.3	434	.7073	728.9

which will express the value of W in terms of the known quantities it is merely necessary to divide the members of Equation 2 by those of Equation 1, thus:

$$W = \frac{\frac{N p_1}{459.2 + t}\left(1.6494 + \frac{0.248\,t}{850 - t}\right)}{2.698192\, N \frac{p_2}{459.2 + t}}$$

which may be simplified by division to give,

$$W = \left(0.6113 + \frac{0.092\,t}{850 - t}\right)\frac{p_1}{p_2}$$

but (by Equation 3) $p_2 = p - p_1$ and by substituting this value of p_2 in the above equation there results:

$$W = \left(0.6113 + \frac{0.092\,t}{850 - t}\right)\frac{p_1}{p - p_1}\text{ ; or,}$$

$$W = \left(0.6113 + \frac{0.092\,t}{850 - t}\right)\frac{H}{2.036\,p - H} \text{ (Equation 4)}$$

where H represents the tension of saturated steam (or water vapor) at the temperature, t, in ins. of mercury.

In order to simplify matters, the first member of Equation 4 may be placed equal to K, thus:

$$W = \frac{K \times H}{2.036\,p - H} \quad \text{(Equation 5)}$$

The values of K and H corresponding to all ordinary temperatures, are given in Table I. That is, Equation 5 is the desired simple formula which gives the maximum weight, W, (in pounds) of water vapor that one pound of pure air can contain when the total or observed absolute pressure in pounds per square inch is p, and the values of K and H correspond to the existing temperature, whatever its value may be. Table I. will also be found of much practical value in other connections by noting that H is simply the absolute pressure of saturated steam expressed in inches of mercury, the absolute pressure in lbs. per square inch being readily found for any desired temperature by dividing the values of H by 2.036; also K represents the ratio of the weight of 1 cu. ft. of saturated steam at any given temperature and corresponding pressure to 1 cu. ft. of pure air at the same pressure and temperature.

It is worthy of note, as demonstrated in the preceding discussion and as proved by numerous experiments, that the ratio just referred to is *not a constant* but has a different value for each temperature, consequently all of the tables heretofore published in text-books and hand-books which give the relative and total weights of air and water vapor and of the mixture, and which have been computed on the erroneous assumption that the ratio in question is a constant, are not to be relied on with any degree of accuracy, as the majority of the values furnished by such tables are far from being correct. Table II. given in this article is figured correctly by the use of the exact ratio for each temperature specified and should prove of much value in all moisture computations — some of its uses are demonstrated by the last two examples of the four, which will now be given to illustrate a few of the important practical applications of Equation 5 and Tables I. and II.

SPECIFIC APPLICATIONS OF FORMULAS AND TABLES.

EXAMPLE 1.—How low must the relative humidity be, when the atmospheric pressure is 14.7 lbs. per sq. in. and the outside temperature is 60°, in order that no moisture may be deposited in any part of a compressed air system carrying a constant gage pressure of 90 lbs. per sq. in.? The relative humidity of the atmosphere is, of course, the percentage of moisture which the air contains at any particular pressure and temperature as compared with the maximum amount which it can hold under the same conditions.

Solution.—In order to solve this problem it is merely necessary to use Equation 5 to determine the maximum amount of moisture that 1 lb. of pure air can contain at 90 lbs. gage pressure (or 104.7 lbs. absolute pressure) and 60° temperature which may be easily done by aid of Table I., thus:

$$W \text{ (at 104.7 lbs.)} = \frac{K H}{2.036\,p - H} = \frac{0.6183 \times 0.5180}{2.036 \times 104.7 - 0.5180} = .001506 \text{ lb.;}$$

and to find the maximum weight of moisture that 1 lb. of air can contain at 60° temperature and 14.7 lbs. absolute pressure, thus,

$$W \text{ (at 14.7)} = \frac{K H}{2.036\,p - H} = \frac{0.6183 \times 0.5180}{2.036 \times 14.7 - 0.5180} = .01089 \text{ lb.;}$$

but in order that no moisture may be deposited in the system, each pound of pure air must not contain over .001506 lb. of moisture, and therefore the relative humidity must not be above the following value:

$$\frac{.001506}{.01089} \times 100 = 13.83\% \quad \text{...(Answer)}$$

This example shows that, unless operating in an extremely dry climate, some moisture is sure to be deposited in the system and that this amount depends on the relative humidity of the atmosphere as well as on the outside temperature and the pressure carried in the main reservoirs.

EXAMPLE 2.—When compressing air into a reservoir carrying a constant gage pressure of 75 lbs., from a saturated atmosphere of 14.7 lbs. absolute pressure and a temperature of 70°, to what temperature must the air be cooled after compression in order to cause the deposition of moisture to commence?

Solution.—To answer this question, first find the maximum weight of moisture contained by 1 lb. of pure air at 14.7 lbs. pressure and 70° temperature, by aid of Table I. and Equation 5, thus:

$$W = \frac{K H}{2.036\,p - H} = \frac{0.6196 \times 0.7332}{2.036 \times 14.7 - 0.7332} = 0.01556 \text{ lb.}$$

then the temperature to which the air must be cooled in order to cause the deposition of moisture to begin may readily be found by placing this value of 0.01556 in Equation 5 together with the value of p equal to 75 + 14.7, thus:

$$0.01556 = \frac{K H}{2.036 \times 89.7 - H} = \frac{K H}{182.63 - H}$$

or $H = \frac{2.842}{0.01556 + K}$ and the temperature which satisfies this equation is found by aid of Table I. to be approximately 129° F. (Answer.)

That is in this case unless the air be cooled to 129° before being drawn from the main reservoirs none of the moisture contained by it will be deposited in these reservoirs, so that the importance of reducing the temperature of the compressed air to that existing outside is clearly seen, for all of the excess moisture will be deposited while the air in this case is having its temperature reduced from 129° to 70° F.

EXAMPLE 3.—When the outside temperature is 82° F., and the pressure of the atmosphere is 14.6963 lbs. per sq. in., the relative humidity being 100%, in what time will one gallon of water be deposited in a main reservoir when the air is cooled to 82°, and the gage pressure is 100 lbs. per sq. in., when a compressor is supplying an average of 30 cu. ft. of the moist atmosphere per minute?

Solution.—To solve this problem it is merely necessary to find the difference between the maximum weight of moisture mixed with 1 lb. of pure air at the two pressures concerned, the temperature being 82° in both cases. For the atmospheric pressure of 14.6963 lbs. the desired weight may be computed by Equation 5 and Table I., or may be more easily found by aid of Table II., which gives the desired value in the eighth column as 0.023526 lb. For 100 lbs. gage pressure, the weight may be found by Equation 5 and Table I., thus:

$$W = \frac{K H}{2.036\,p - H} = \frac{0.6211 \times 1.092}{2.036 \times 114.6963 - 1.092} = 0.002918 \text{ lb.}$$

and therefore the weight of moisture deposited by each pound of pure compressed air is 0.023526 — 0.002918 = 0.020608 lb. Now Table II., column 6, shows that each cu. ft. of the moist atmosphere contains 0.070595 lb. of pure air, therefore the number of cu. ft. that must be delivered to cause 1 lb. of water to be deposited is:

$$\frac{1}{0.070595} \times \frac{1}{0.020608} = 687.37 \text{ cu. ft.}$$

and one gallon of water weighs 8.32 lbs. (approximately) at 82° F., therefore 8.32 × 687.37 = 5,719 cu. ft. of the moist atmosphere must be

TABLE II.—WEIGHTS, IN LBS., OF PURE DRY AIR, WATER VAPOR AND SATURATED MIXTURES OF AIR AND WATER VAPOR AT VARIOUS TEMPERATURES, UNDER NORMAL ATMOSPHERIC PRESSURE OF 29.921 INS. OF MERCURY OR 14.6963 LBS. PER SQ. IN. ALSO VALUES OF THE ELASTIC FORCE OR PRESSURE OF THE AIR AND VAPOR WHEN PRESENT IN SATURATED MIXTURES. (Copyright, 1908, by H. M.-Prevost Murphy.)

Temperatures in Fahrenheit Degrees.	Weight of One Cubic Foot of Pure Dry Air	Saturated Mixtures of Air and Water Vapor					
		Elastic Force of the Water Vapor or Saturated Steam in Inches of Mercury	Elastic Force of the Air alone when Saturated with Water Vapor in Ins. of Mercury	Weight of the Water Vapor in One Cu. Ft. of the Mixture, or Wt. of One Cu. Ft. of Saturated Steam	Weight of the Air in One Cubic Foot of the Mixture	Total Weight of One Cubic Foot of the Mixture	Weight of Water Vapor Mixed with One Pound of Pure Air
0	.086354	.0439	29.877	.000077	.086226	.086303	.000898
12	.084154	.0754	29.846	.000130	.083943	.084073	.001548
22	.082405	.1172	29.804	.000198	.082083	.082281	.002413
32	.080728	.1811	29.740	.000300	.080239	.080539	.003744
42	.079117	.2673	29.654	.000435	.078411	.078846	.005554
52	.077569	.3883	29.533	.000621	.076563	.077184	.008116
62	.076081	.5559	29.365	.000874	.074667	.075541	.011709
72	.074649	.7846	29.136	.001213	.072690	.073903	.016691
82	.073270	1.092	28.829	.001661	.070595	.072256	.023526
92	.071940	1.501	28.420	.002247	.068331	.070578	.032877
102	.070658	2.036	27.885	.002999	.065850	.068849	.045546
112	.069421	2.731	27.190	.003962	.063085	.067047	.062806
122	.068227	3.621	26.300	.005175	.059970	.065145	.086285
132	.067073	4.750	25.171	.006689	.056425	.063114	.118548
142	.065957	6.167	23.754	.008562	.052363	.060925	.163508
152	.064878	7.929	21.992	.010854	.047686	.058540	.227609
162	.063834	10.097	19.824	.013636	.042293	.055929	.322407
172	.062822	12.749	17.172	.016987	.036055	.053042	.471146
182	.061843	15.965	13.956	.021000	.028845	.049845	.728012
192	.060893	19.826	10.095	.025746	.020545	.046291	1.25319
202	.059972	24.442	5.479	.031354	.010982	.042336	2.85507
212	.059079	29.921	0.000	.037922	.000000	.037922	Infinite

Note.—Air is said to be saturated with water vapor when it contains the maximum amount possible at the existing temperature and pressure.

delivered to cause one gallon of water to be deposited, and the time required with the 30-cu. ft. compressor will be:

$$\frac{5{,}719}{30} = 191 \text{ min. (approx.)} = 3 \text{ hrs., } 11 \text{ min.}$$

(Answer.)

This example shows clearly that a large amount of moisture may be deposited in a very short time, under certain conditions, and thus emphasizes the importance of frequently draining the main reservoirs, which if not properly attended to may not only have their air storage capacity greatly depleted by the presence of the water, but may in time become so full of it that there will be no room left for the deposition of additional moisture and consequently the radiating system will be rendered of no value.

EXAMPLE 4.—With the same system and under the same conditions as those stated in Example 3, what is the loss in volumetric efficiency of the plant when the excess moisture is properly trapped in the main reservoirs?

Solution.—To solve this problem it is merely necessary to proceed as follows: Table II. shows that, before compression, each pound of pure air is mixed with 0.023526 lb. of water vapor and that the weight of 1 cu. ft. of the mixture is 0.072256 lb., consequently the volume of the 1 lb. of air and 0.023526 lb. of vapor is

$$\frac{1.023526}{0.072256} = 14.165 \text{ cu. ft.}$$

Now for 100 lbs. gage pressure and 82° temperature, it was shown in Example 3 that 1 lb. of pure air can hold only 0.002918 lb. of water vapor in suspension, each pound of air having deposited 0.020608 lb. of water in the main reservoir. Also Table II. shows that the weight of 1 cu. ft. of pure water vapor at 82°, and at the corresponding tension of 1.092 ins. of mercury, is 0.001661 lb., consequently by Dalton's law the volume of the mixture consisting of 1 lb. of pure air and 0.002918 lb. of saturated water vapor (or steam), at 100 lbs. gage pressure is the same as that of the saturated steam alone under the conditions just mentioned, that is, the volume of the mixture is:

$$\frac{0.002918}{0.001661} = 1.757 \text{ cu. ft.}$$

(This value may easily be checked by finding the pressure in inches of mercury of the 1 lb. of pure air when compressed into this volume, which when added to 1.092 will give the total pressure of the mixture, namely, the absolute pressure in inches of mercury corresponding to 100 lbs. gage pressure.)

Finally (by Marriotte's or Boyle's law), the volume of these 1.757 cu. ft. of mixed gas at 114.6963 lbs. absolute pressure when expanded to atmospheric pressure will be,

$$\frac{114.6963}{14.6963} \times 1.757 = 13.712 \text{ cu. ft.;}$$

consequently the decrease of volume, that is, the loss of volumetric efficiency is,

$$14.165 - 13.712 = 0.453 \text{ cu. ft., or } \frac{0.453}{14.165} \times 100 = 3.2\%. \text{ (Answer.)}$$

This example shows clearly that, particularly in warm, moist climates, there is a very appreciable loss in the efficiency of compressors, due to the condensation of water vapor. Of course this loss is unavoidable in railway work, and is far preferable to allowing the moisture to pass into the working parts of the system, but in stationary work where reheaters are used, this cause of decreased efficiency may be obviated, and this problem should be of particular interest in this connection, as losses due to this cause have not been carefully considered heretofore and yet may clearly play a very important part in the economical operation of compressed air plants.

THE FORT GARRY TERMINAL; A UNION STATION AT WINNIPEG, MAN.

[With two-page Inset.]

By J. D. MATHESON.*

The present Winnipeg passenger station of the Canadian Northern Ry. is located on Water St. just east of Main St., close to the center of the city. This station and the adjoining train-shed have been entirely outgrown by the rapid increase of importance of Winnipeg as a traffic center. Further east on Water St. is the present freight-shed, 800 ft. long, which is in poor condition and is also too small to handle its business. The team yard, of 150 cars capacity, adjoining the freight-house, has similarly been outgrown. It therefore became apparent to the officials of the Canadian Northern that in order to handle the present traffic properly and to be in a position to make enlargements in the future, as business further increases, a wholly new arrangement of both passenger and freight facilities would be necessary, on a much larger area than now occupied.

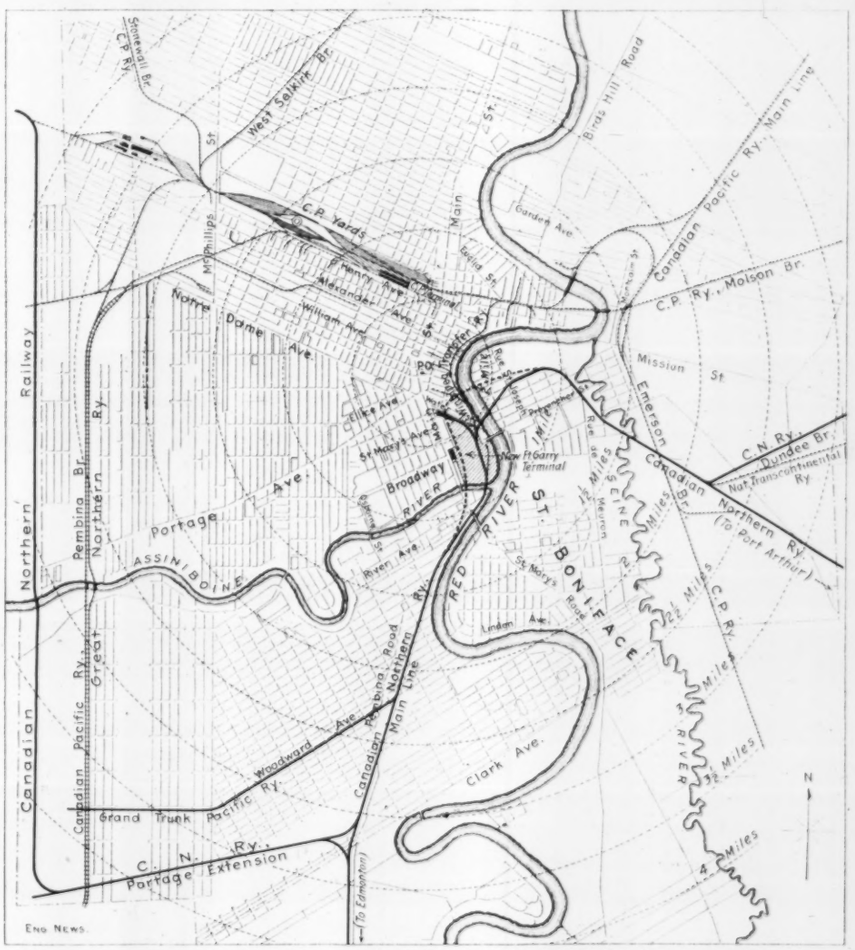


FIG. 1. MAP OF THE CITY OF WINNIPEG.

At about this time the Grand Trunk Pacific Ry. and the Transcontinental Ry. of Canada (now nearing completion and soon to commence operation) were making investigations for a terminal in Winnipeg. An agreement was finally reached between the three roads to join together in a union terminal of both passenger station and yard and local freight yards and freight-houses, to be operated jointly. The design of this terminal has now been completed, and construction began about two weeks ago. It is expected that it will be used also by the Great Northern R. R., whose passenger trains now enter the present Canadian Northern station. The new terminal adjoins the site of old Ft. Garry, built in 1822 to protect the trading post, which was the beginning of the present city of Winnipeg. The name of the fort has therefore been applied to the new station.

An area of about twelve acres a short distance southeast of the existing station is now occupied by the engine-houses, car and machine shops and storehouses of the Canadian Northern Ry. These have recently been replaced by a new plant of engine-house and car-shop facilities at the general railway yards of the company, about a mile west of Main St. The vacated area formed the nucleus of an excellent terminal site, and the railway companies, with creditable foresight, acquired at great cost the entire remainder of the property bounded by Main St., Water St., and the Red and Assiniboine rivers, with the exception of lots fronting on Main St. (see the map, Fig. 1). A total area of about 70 acres was thus made available for terminal purposes.

This area is at present cut through by Broadway from Main St. to the Broadway bridge over the Red River. It was evident that the property could not be developed for railway terminal purposes unless the street were closed from Main St. to the river. The city was unwilling to do this, largely because the street gives access to the recently built Broadway bridge, which provides for vehicular and pedestrian traffic between Winnipeg and the town of St. Boniface, which lies beyond the Red River, and itself is rapidly developing into a large and busy town. Finally a compromise agreement was reached between city and railways to the effect that the new passenger station and office building was to be located on Main St. opposite Broadway, in consideration of the city's closing Broadway thence to the river, and the railway companies were to provide street connection between the east end of Water St. and the Broadway bridge. It had previously been the intention to locate the new station at the corner of Main and Water

*Assistant Engineer, Warren & Wetmore, Architects, 3 East 33d St., New York City.

Sts., on practically the same site as the present station, which would be somewhat more convenient because closer to the center of the business district.

The design of the general plan and all details of the new terminal was entrusted to the architectural firm of Warren & Wetmore, of New York City. They were instructed that they might disregard all existing facilities, including even the river bridges, and make a layout using the total acquired area of property, as noted above, for passenger yard, train shed, local delivery yards and freight-houses, of maximum capacity. The only predetermined feature was the location of the station building opposite Broadway. The plan shown herewith as Fig. 2 is the final outcome of their work.

The Canadian Northern Ry. commenced operation in December, 1906, with 100 miles of road. It has now 3,800 miles in operation, and is extending its lines rapidly. Its traffic is increasing at such a pace that the past records of traffic handled were of little use in determining the probable future business to be provided for. The Grand Trunk Pacific Ry., being an entirely new road, mostly through new and undeveloped country, and not at present in operation, also offered no means of determining the requisite capacity of necessary facilities to be provided.

It was at first desired by the railway companies to have this terminal site provide for the passenger coach-yards and engine-houses for both yards. After several alternate layouts had been made, however, it became evident that an ideal layout for the passenger yard and train-shed and the local freight delivery yards and freight-houses of a capacity which, according to careful estimate, would be required in the not distant future could be made only by devoting the entire area to these purposes. Accordingly the Canadian Northern has provided for engine and coach-yard facilities at its general yards, as already noted, in conjunction with its car and machine shops and storehouses. The Grand Trunk Pacific has likewise provided for these facilities at its general yards now under construction about three miles east.

GENERAL PLAN: ALTERNATIVE LAYOUTS.—The first layout made contemplated a stub-end terminal passenger station, using a wye track beyond the Red River at St. Boniface, backing all trains across a new bridge over Red River and into the station. The train-shed was laid out at an angle of about 45° with Main St., the local freight-yards and freight-houses being between the train-shed and Water St. Using the same type of stub-end terminal an alternate layout was made having train-shed parallel to Main St., with local freight-yard and freight-houses likewise parallel to Main St., and reached by driveways from Water St. In this case the wye would be located directly south of the station building, therefore necessitating bridges over both the Red and Assiniboine rivers. The use of a wye track located on the St. Boniface side necessitated abandoning the present main line of the Canadian Northern Ry. for about a mile west of Main St., crossing the Red River on a new bridge and using an entirely new line to a connection with the present main line about 1½ miles east of Main St.

The advantages of the stub-end type of terminal were its avoidance of grade crossings of streets near the terminal, its suitability to the severe winter climate of Winnipeg—since the train-shed would be enclosed on three sides—and the convenient accessibility to platforms direct from concourse by the passengers. They were offset, however, by the fact that the distance between the wye and the terminal would be at least one-half mile, thereby rendering impossible the efficient operation and dispatch of trains during busy periods, and making a serious increase in the running time of through trains, due to the long back-up. These reasons led to the adoption of the through station type of terminal, as shown by the general plan Fig. 2. This design unquestionably affords efficient operation of both through and local trains.

With the through station, it was considered that the best platform arrangement was the use of island platforms between successive pairs of tracks, reached by stairways from a transverse passage below. This would fit well with an elevated structure, such as was demanded in order to cross above Main St., also Water St. and the streets northeast of this in the approach to the Red River crossing. The elevated station trackage would also permit of placing the baggage and express rooms below the tracks, with direct service to the platforms by elevators. This is contemplated in the complete scheme, but for initial construction (only about one-half of the layout will be built at first, the remainder to be added as increased traffic demands it) the express and baggage will be handled in the ground floor of the south (right-hand) wing of the station.

The question of a covering over the station tracks engaged careful consideration. A large single-span train-shed, which would necessarily be open at both ends, was not thought advisable, as giving no protection in winter. It was finally decided to provide for a train-shed of the covered canopy type similar to that of the Lackawanna's New York terminal at Hoboken, N. J. Such a shed is free from smoke and steam and is dry and well lighted, and gives a maximum of protection to the passengers. For the initial construction it is probable that wooden butterfly canopies over the platforms will be built.

PASSENGER STATION.—The station building, to be located on Main St. directly opposite Broadway as fixed by the agreement with the city, was required to provide for all necessary passenger facilities, and offices for the railway service. In anticipation of large future increase in the requirements for offices, it was desired to provide for future extension in this respect.

Since the development of the great territories of western Canada will be accomplished mainly through immigration, it is to be expected that a large immigrant traffic will have to be handled at Winnipeg, the natural distributing center. Special provisions needed to be made for this traffic, and this has been done by separating the immigrant facilities from the other passenger facilities, assigning them one entire wing of the basement floor.

The station building as designed is an imposing structure of stone (Figs. 3 and 5), having a length of 350 ft. along Main St. and a width of 140 ft. The height of the larger portion of the building will be three stories and basement, with an elaborate central portion, having great arched windows on all four sides, and surmounted by a dome 100 ft. high above street level directly opposite the center of Broadway. The main entrance will be off Main St. at the center of building beneath a large stone arch.

The main floor is at the street level. Its plan, as finally adopted, for convenience to passengers and facility of operation represents the highest type of modern passenger station design (Fig. 4). The central portion is a rotunda and ticket lobby, a circular space 90 ft. in diameter unobstructed by columns, seats or booths. The large windows of the dome, opening respectively to front and rear and to interior courts of the wings, give this lobby ample light. The waiting room is placed to one side, occupying the north wing, so that the waiting passengers are separated from the streams of moving people passing to or from street, trains, ticket-window, baggage-counter, etc. The exit to trains is at the back of the lobby, directly opposite the entrance door, and opens into a subway under the tracks, leading to the several stairways to the train platforms.

The waiting-room, being in a separate room, is thereby freed from confusion and disorder and serves the convenience of waiting passengers more effectively. It has a floor area of 9,000 sq. ft. and is set with movable oak benches, giving a very large seating capacity. Wash rooms adjoin on the east, and a restaurant and lunch-room on the west (front of building), the latter rooms having also entrances off the street. The central part of the waiting-room is covered by a 40 × 100 ft. arched skylight, above which is the interior court of the north wing.

A special feature has been made of the construction of the skylights. They are composed of vault-lights in panels, made absolutely water-tight, which (in a region of heavy snow-falls and extremes of temperature) will prevent the annoying leaks and drafts incident to large skylights of ordinary construction in this climate.

The interior of waiting-room and ticket-lobby will have the effect of stone construction throughout, the wainscoting being of marble 6 ft. high, and the floors of terrazzo. This construction gives not only a very attractive appearance to the rooms, but has the advantage of being sanitary and readily cleaned. All stairways will be of iron with marble treads.

The entire south wing of the main floor will for the present be occupied by baggage and express rooms. In the future, when more space is required, both the baggage and express will occupy space beneath the tracks and platforms adjoining rear of building, as already mentioned, and the south wing may then be used for additional waiting-room space or for other station purposes. A driveway for baggage and express wagons is provided at the south end of building; it is 3 ft. 6 ins. below the level of the main floor, and is reached by a short 5% grade down from Main St. The wagons are loaded and unloaded on an 8-ft. platform outside of the building wall, which spans the basement areaway below. The baggage and express will be handled by hand trucks between the building and the train platforms, through trucking subways beneath train-sheds, and by electric elevators from subways to each platform at either end of train-shed.

The basement floor is 15 ft. below the level of Main St. The entire south wing of this floor is devoted to emigrants. There is an emigrants' waiting-room, having a lunch counter on the north side and a laundry and separate men's and women's bathrooms on the east side, a men's smoking-room and a women's waiting-room, each with toilets. The emigrants are conducted to and from the waiting-room and trains by means of a stairway at rear of building, leading direct from basement to passenger subway. A separate emigrants' entrance off Main St. is provided leading down from street to basement, partly by a stairway and partly by ramp. Emigrants thus are well provided for and can be handled to and from both trains and the street without coming into contact with other passengers.

In the north wing of basement floor is a barber-shop, the kitchen, which supplies the restaurant and lunch-rooms directly overhead, and the boiler and engine-rooms with the heating and ventilating apparatus. There will be four heating boilers of 150 HP. each.

Under the central portion of building, the basement floor will be used for storage of sleeping and dining car supplies, and miscellaneous storage purposes. The basement is surrounded on all four sides by an open areaway 10 ft. wide, which supplies light and air to the basement rooms.

The second and third floors will be occupied entirely by the local and general western offices of the railways. These offices are on either side of a corridor, the interior row of offices in each wing facing on the open court. Each floor provides an available office space of 25,000 sq. ft., exclusive of corridors, stairways, elevators and toilets.

Provision has been made in the design of the foundations and the steel structure for the future addition of six office floors, so that the building will then provide 200,000 sq. ft. of office space.

The apportionment of space in the station is shown in condensed form by the table below:

STATION FLOOR AREAS, FORT GARRY TERMINAL.

	Sq. ft.
Main Floor:	
Ticket-lobby	11,000
Waiting-room	9,000
Lunch-room	1,300
Restaurant	2,200
Men's room	1,800
Women's room	1,800
Baggage and express room	18,000
Basement:	
Emigrants' waiting-room	10,000
Smoking-room	3,000

Women's room	3,000
Barber shop	1,300
Kitchen	6,000
Boiler and engine rooms	9,500
Storage	8,000

Upper Floors: Offices, 25,000 sq. ft. per floor.

In these several amounts of space allowed, and also in the layout of the passenger tracks, ample provision has been made for the probable rapid growth of Winnipeg. The architects believe that the station as designed will meet all demands upon it for many years. In their planning they have profited by the experience with the Canadian Pacific Ry. station at Winnipeg, which, though completed less than three years, has already become inadequate to handle the traffic presented during busy periods.

The building is so designed that there will be no necessity for artificial lighting in any portion during the day. In the ticket-lobby the lamps for the greater part are concealed, and in addition there will be a large chandelier containing 150 lights, suspended above the center of lobby. Heat will be supplied by steam, using indirect radiation on the main floor, and direct on the office floors.

The structure of the building will be of the steel skeleton type. The column loads will be supported at the foundations by concrete piles, each pile to carry a load of 35 tons. The character of the soil at the site is the blue clay common to Winnipeg, the supporting power of which cannot be relied upon to sustain a greater load than 3,000 lbs. per sq. ft. The use of concrete piles is necessary owing to the fact that the piles will be between the high and low-water lines of the Assiniboine River, which is about 1,000 ft. from the building. The stone used in the construction of the facades will be either Indiana limestone or the native "Tyndall" stone, of Southern Manitoba.

PASSENGER YARD.—The track layout for both the passenger and freight-yards, as shown on the plan, Fig. 2, was developed after much study by the officials and engineers of both railway companies, in cooperation with the architects. The plan shows the maximum development, the passenger tracks comprising eight through passenger tracks with platforms, and two separate open running tracks at rear for through freight trains. The platforms are 20 ft. wide and can be made 1,650 ft. in length. By means of this great length and by the use of double cross-overs, as shown, each track is capable of handling two trains of eleven cars each during periods of heavy traffic. The total capacity of the platforms will be 200 70-ft. cars. The platforms will be of reinforced concrete, with surface 12 ins. above base of rail. Between each pair of tracks there will be three lines of pipe, for water, steam and gas.

Passengers going to trains pass from the ticket-lobby into a subway 50 ft. wide, with headroom of 10 ft., having 7-ft. stairways on either side leading up to each platform. This subway is so arranged by means of railings and gates that there will be no interference between passengers going to and coming from trains. The subway will be heated in winter from the building. The elevation of tracks over the subway will be 10 ft. above level of main floor of station; a slight incline down from the rear of ticket-lobby to floor of subway allows a clear headroom of 10 ft. The future baggage and express sheds under the tracks will have a clear headroom of 10 ft. They will be approached from a 50-ft. driveway 3 ft. 6 ins. below floor of shed with a 4% grade down from Main St. south of the station building.

FREIGHT SHEDS AND YARD.—The problem of obtaining a layout for local freight delivery yard and freight sheds giving sufficiently large team track capacity, long freight sheds, equal facilities for each road, and allowing greatest accessibility for teaming, while at the same time suited to be properly worked by switching, was complicated by the peculiar shape and conditions of the ground layout, and by the fact that the throat of the yard had to be located on a bridge across the Assiniboine River. The layout adopted, Fig. 2, gives the greatest car capacity, as well as the greatest facility of operation and access to team hauling, of several tentative layouts which were drawn and studied.

The team yard contains 42 tracks, with a total capacity of 830 40-ft. freight cars. The switching leads to this yard are divided by cross-overs into three separate portions each controlling 13 tracks, so that three switching engines may be worked at the same time. The usual length of team tracks is 800 ft., with a capacity of 20 cars each. Adjacent pairs of team tracks are on 12-ft. centers; opposite tracks are 40 ft. on centers across the driveways.

The team driveways will be of stone block construction on a 6-in. concrete base. This construction is made necessary by the treacherous character of the clay soil, which, when wet, will heave and swell, causing an ordinary light pavement to break and disintegrate. The driveways are 30 ft. wide between curbs. Tapping the ends of these driveways is a paved avenue from 60 to 70 ft. wide, running the full length of the yard. The surface drainage from all the driveways will be by means of gutters along each side of each driveway, ending at catch-basins located at the ends of the driveways on the east side of the wide avenue, which catch-basins discharge into a line of vitrified tile pipe discharging into the Assiniboine River.

The freight sheds comprise two equal sets of inbound and outbound sheds, one set for each road. The outbound sheds are 40 ft. wide and 1,000 ft. long, each served by four tracks. The inbound sheds are 60 ft. wide and 900 ft. long, each served by two tracks. Between these inbound and outbound tracks is a 10-ft. transfer trucking platform. Each road will therefore have a freight-shed track capacity of 144 40-ft. cars. The freight-sheds will be one story high; they will consist of steel columns and roof trusses, roofed with tin, and have sliding doors on both the track and team sides, with wire-glass transoms above. The floors will be of wood laid on a compacted cinder fill. At the west ends of the freight sheds, in the second story, are the freight offices, with 15,000 sq. ft. of space for each road. A bridge 40 ft. wide at the level of these office floors will span the six intermediate tracks and connect the outbound and inbound sheds. The freight agent's office will be located on this bridge, where he can view the loading and unloading of cars.

The switching leads to the freight-sheds are of such length that the tracks may be switched without the switch engine having to cross the bridge at throat of yard. The supporting yard has a total capacity of 385 cars. This yard is for the reception and storage of arriving trains of loaded cars to be switched into the team-yard and for departing trains of empty cars which have been switched out from the team tracks.

The sharpest curves used in the freight-yard are 14°, radius 410 ft. The frogs used are mostly No. 7, with No. 10 for main track connections and main cross-overs. The track construction in the freight-yards will have 60-lb. rails and gravel ballast.

As the railway companies will each have its own cartage company to handle trucking, there will be provided adjacent to the team-yard two stable buildings, each to accommodate 200 horses. The buildings will be of brick construction, two stories high, the upper floor being used for feed and harness storage. A cartage company warehouse of brick construction will also be provided for the storage of freight not claimed by consignee within a reasonable length of time.

APPROACHES TO PASSENGER TERMINAL.—The west approach will start from the present main track on the north bank of the Red River about 2,000 ft. west of Main St., and ascending on an earth embankment at maximum ruling gradient of 0.4% will pass over Main St. on a double-track plate-girder bridge, allowing an underclearance of 14 ft. for the street roadway. It will then cross the Assiniboine River on a new double-track steel truss bridge 400 ft. in length, one span of which will be a swing-bridge, as required by the Government. The east approach starts from the present main line, near the St. Boniface Station, and rises on an earth embankment, with the ruling 0.4% gradient, to the Red River, which it crosses on a new double-track steel truss bridge 900 ft. in length, containing one draw-span, as required by the Government.

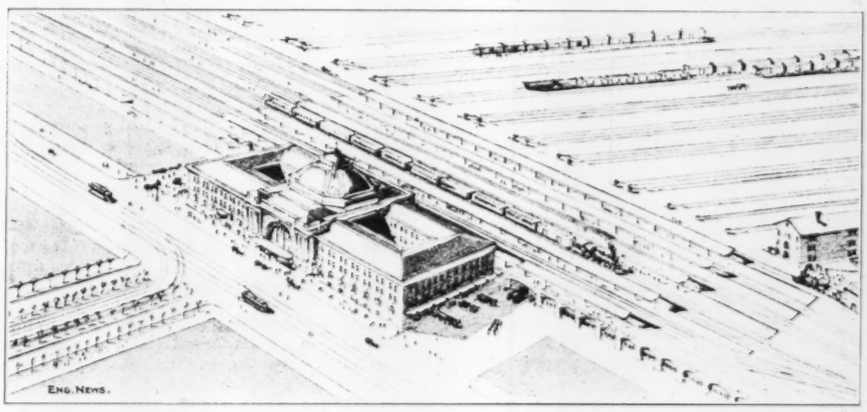


FIG. 5. PERSPECTIVE VIEW OF FORT GARRY TERMINAL STATION AND PART OF PASSENGER YARD.

It then crosses on steel plate-girder bridges the Winnipeg Transfer Railway, Mill St., Notre Dame Ave. and Water St. Each of the street roadways will have at least 14 ft. clear headroom. The profile will be practically level from the Red River Bridge to the Assiniboine River Bridge.

At each end of the passenger yard there will be a signal tower from which all signals, switches and cross-overs will be controlled, with electro-pneumatic interlocking. All track work will be of first-class construction, with 80-lb. rails and gravel ballast.

While the Government requires all bridges across either the Red or Assiniboine Rivers to contain draw-spans, these rivers are not navigable at the present time for any but small boats, and the draw-spans are open only a very few times in the course of a year.

APPROACHES TO FREIGHT-YARD.—The present main track crosses the Assiniboine River on a wooden drawbridge, which will be replaced in the new scheme by a steel four-track rolling-lift bridge of two leaves. The Red River is crossed by the present main track on a comparatively new steel truss bridge, the shore span of which is shown by the plan near the end of Water St. This bridge will be maintained for the proposed new layout and used mostly by the Grand Trunk Pacific for local freight running between this terminal and its general freight-yard. The adjacent shore span will need to be reconstructed to meet the change in alinement of running track, as shown. The west

approach to freight-yard will use the same line and be at the same level as the present main track. The length of all switching leads for each part of the freight-yards is such that no switching whatever will be done across Main St. The only traffic across this street will be that of trains of local freight between this terminal and the Canadian Northern general freight-yards. All the through freight trains for both roads will be run on the two open running tracks back of the passenger platform tracks. At the north end of the new Assiniboine River Bridge there will be located a signal tower, from which will be controlled, by electro-pneumatic interlocking, all the signals, switches and cross-overs of the tracks entering the bridge.

A connection will be maintained with the present Winnipeg Transfer Ry. track, along which are located numerous industrial sidings, and over which cars for transfer with the Canadian Pacific Railway are handled. This connection will pass beneath the east approach near Lombard Ave.

The railway officials who cooperated for the construction of these joint terminals are: Mr. William Mackenzie, President, Mr. D. D. Mann, Vice-President, and Mr. M. H. McLeod, General Manager, of the Canadian Northern Ry.; and Mr. Charles F. Hays, President, Mr. Frank W. Morse, Vice-President and General Manager, and Mr. D. B. Kelliher, Chief Engineer, of the Grand Trunk Pacific Ry.; and the Commissioners of the National Transcontinental Ry., Hon. S. N. Parent, Chairman.

The station building and track layout of both passenger and freight-yards were designed by Messrs. Warren & Wetmore, 3 East 33d St., New York City, who will also supervise the entire construction. Mr. A. R. Whaley, Manager Grand Central Terminal, New York Central & Hudson R. R., was consulted by the architects and gave valuable advice regarding the operating features of the passenger and freight-yards.

The contract for the construction of the station building has been let to Peter Lyall & Sons, of Montreal and Winnipeg. Active work on the contract is now in progress, under the writer's superintendence.

QUENCHING COKE WITHOUT WATER.

A process of quenching coke when drawn from the oven without the use of water has been recently patented. The advantage claimed for the process is the production of a very much harder coke which can bear a greater burden in the blast furnace without crushing. It is also claimed that good coke can be produced from many non-coking coals by the aid of this process. Further, the coke produced is absolutely dry, while ordinary coke contains often as high as 10 to 12% of moisture. Very likely the coke produced by the dry process would gradually absorb moisture from the air; but it would never become over saturated as ordinary coke often is.

The process referred to is the invention of Mr. Chas. E. Arnold and is covered by U. S. patent No. 842,747. As described, the incandescent coke, as soon as removed from the oven is transferred to a cooling chamber from which air is excluded, and the small amount of air admitted with the coke soon has its oxygen used up. A current of cold inert gas—nitrogen and carbonic dioxide—is then forced into the coke chamber, takes up heat from the incandescent coke and as it passes out goes over cooling coils in which water is circulated. After cooling, the gas is again forced into the chamber and the cycle continues until the coke is cooled below the ignition point, when it can be removed to the open air. If desired the heat taken up by the circulating water in the cooling coils can be utilized. We are informed that tests on a small scale have shown the process to be practicable and to produce a coke much superior to that quenched in the ordinary way.

IRRIGATION WORKS IN MEXICO are to be stimulated by a Government appropriation of $25,000,000, which was finally ratified on June 5. The money is to be given as subsidies to private irrigation companies.

TEST OF AN AIR-LIFT PUMPING PLANT AND EXPERIMENTAL STUDIES OF AIR-LIFT PUMPS.

Two series of tests on air-lift pumps, whose results have recently come to our knowledge, give interesting information in a field where the previously published data on performance and possibilities are extremely scanty.

TESTS OF AIR-LIFT PUMPING PLANT AT ATLANTIC CITY.

The water-supply system of Atlantic City, N. J., was supplemented a few years ago by ten wells. Air-lift pumping equipment was put in, on the basis of competitive bids which made this appear the cheapest to instal. The acceptance and the contract price were conditioned on capacity and duty tests of the system, and a full series of such tests was made when the installation was completed. The results showed a satisfactory duty, ranging roughly from 20,000,000 to 25,000,000 ft. lbs. work per 1,000 lbs. dry steam.

The following is a brief general description of the plant and the tests, from data given in a paper read recently before the Engineers' Club of Baltimore by Mr. Kenneth Allen, former Engineer of the Water Department of Atlantic City. The wells were put in to supplement the Absecon Creek supply of Atlantic City, introduced by R. D. Wood & Co. in 1882. In 1895, after the city took over the works, a 10-in. and a 4½-in. self-flowing well were put down, and by a 1,000,000 gal. Worthington pump these yielded a maximum supply of 840,000 gals. per day. In 1903 ten more wells were sunk, and these, with the earlier two, were equipped with air-lift. Since then, Mr. L. Van Gilder, Engineer of the Water Department, has sunk two more wells, and it is thought that ultimately the well supply will entirely supplant the highly colored Absecon Creek supply. The tests in question were made in the summer of 1904, and cover the first twelve wells.

These wells are generally 10 ins. in diameter and averaged 101 ft. deep; they were spaced 125 ft. apart. One well was only 43 ft. deep. The wells were jetted down, with little hard ramming, penetrating black soil and extending deep into a rather fine sand interspersed with some beds of clay and gravel. The first two wells sunk were fitted with 20 ft. of Cook strainer at the bottom, but in the others 20 ft. of common gauze strainer was added above the Cook strainer. The cost of the ten wells was $1,142, and the cost of a line of vitrified discharge main, 6-ins. to 18-ins., was $2,606.70. The pipes discharged into a concrete weir chamber built by the city; in this chamber was a thin-edged brass weir, hook-gage, etc., for measuring the pumpage.

The types of pumping equipment considered were, besides the air-lift plant, (1) a centrifugal pump driven py an impulse wheel actuated by water piped from the force-main, and (2) a centrifugal pump driven by electric motor, with feed line and generator. In both cases a deep suction main from the wells to a pump basin near the station would be required, and the cost of this promised to be so great, on account of the depth and the saturated character of the soft soil, that the air-lift plant was the most economical. The Pneumatic Engineering Co., of New York City, contracted for the machinery and pumping appliances complete.

This comprised a Rand duplex flywheel compressor, having 10-in. and 16-in. cross-compound steam cylinders of 12-in. stroke, 13 × 12-in air cylinders, Corliss inlet valves and poppet discharge valves, designed for 3,000,000 gallons per day on a lift of 30 ft., with steam at 80 lbs.; a compressor of the same type, with 11-in. and 18-in. × 14-in. stroke steam end and 16 × 14-in. air end, having Meyer adjustable valves on the steam cylinders; a Wainwright surface condenser; a Deane combined wet vacuum and circulating pump, with 5½ × 7-in. steam end and 6 × 7-in. pumps; an air receiver 28 ins. × 8 ft.; and galvanized piping to the wells, with valves. A capacity of 4,000,000 gallons per day was desired, and the smaller compressor was to be in reserve. The contract price for the pumping equipment complete was $8,250 plus an addition at the rate of $2,645 per million gallons by which the capacity should exceed 3,000,000 gallons per day, on test, no excess over 4,000,000 gallons being paid for. A bonus for high duty was also provided, as noted below.

The tests comprised a test for capacity and two tests for duty. In the test for capacity, 11 of the 12 wells were pumped. In this test, according to the contract, the plant was run full for six days, using the larger compressor only, and on the sixth day the total water delivered "with a mean lift of not over 40 ft.," and the water level in the wells, were observed for six hours, this delivery being taken as representing the rated capacity of the plant. The lift was measured as the difference in level between the water surface and the top of casing. An ingenious arrangement for measuring the height of the water surface was employed: A ¼-in. pipe was inserted in the annular space between casing and discharge pipe. The air supply was connected to the top of the small pipe, which blew out the water. The air then being shut off, a gage on the pipe indicated the air-pressure remaining, which was equal to the submergence of the small pipe. The length of this pipe being known, the elevation of the water surface was readily determined.

The tests for duty were made at full rated capacity (using the large compressor and 11 wells) and at about two-thirds rated capacity (in which only 8 wells were pumped). The contract stipulated that the duty was to be computed by adding 7/10 the duty at full capacity and 3/10 the duty at two-thirds capacity. A bonus and reduction of about 5% of the contract price was provided for each million foot-pounds by which this duty exceeded or fell short of 22,500,000.

The capacity test, with steam-pressure averaging 97.8 lbs., vacuum 21.56 ins., and air-pressure 31.56 ins., gave a capacity of 3,705,600 gallons per 24 hrs., with a mean lift of 28.70 ft.

The test for duty at full capacity was made with average steam pressure 100 lbs., vacuum 24 ins., air-pressure 31 lbs., and compressor running at 130 r. p. m. It showed a discharge at the rate of 3,544,900 gals. per day with mean lift of 26.88 ft., and required 9,990 lbs. steam in 6 hrs., of which about 10% was used by the vacuum pump. The duty is 19,923,663 ft.-lbs.

The test for duty at two-thirds rated capacity was made with steam pressure of 100 lbs., 25 ins. vacuum, air-pressure 26 lbs., and compressor running at 78 r. p. m. The lift averaged 25.43 ft., the rate of delivery per day 2,642,870 gallons, and the steam consumption 5,800 lbs., of which the vacuum pump used some 15%. The duty was 24,206,950 ft.-lbs. per 1,000 lbs. steam.

The resultant duty, calculated as specified, was found to be 21,208,650 ft.-lbs. However, as the vacuum pump, a combined circulating and vacuum pump, had been used with water end disconnected, it was considered that its steam consumption was greater than properly chargeable to the vacuum service. A special test was made to determine the error from this source. By running the pump first in combined service, and then successively as vacuum pump only and as circulating pump only, under conditions similar to those of the duty tests, an estimate was obtained of the proportion of steam consumption in combined service that would properly be chargeable to the vacuum pumping. Using this amount in place of the actual condensation from the vacuum pump, the total steam consumed was decreased by 4 to 7%. The duties calculated on the corrected basis were: Full capacity, 20,732,900 ft.-lbs.; two-thirds capacity, 26,346,450 ft.-lbs.; combined, 22,417,000 ft.-lbs.

It is worth remark that the lower delivery in the two-thirds capacity test was accompanied by reduced discharge from the individual wells, and under these circumstances, it appears, the duty is more than 25% higher than when the wells were forced to the deliveries attained in the full-capacity test.

Mr. Allen says, in his paper:

Data on the duty of air-lift plants based on carefully conducted tests are difficult to find. Up to the present time most of the reliable information of the kind is in

the hands of the several companies or firms which make a specialty of such work, but conversation with some of their representatives leads one to the belief that the subject has not yet been brought down to a scientific basis. Extraordinary claims are made of the efficiency resulting from certain patented foot-pieces or jets, etc., but experiments carried on by the contractors on the piping of these wells and on various foot-pieces at other wells owned by the department indicate that while the best results depend largely on the percentage of submersion, diameters of air-pipes and a form of jet that will discharge the air so as to form a multitude of fine bubbles instead of a few large ones, there is no great gain to be found in any special device.

With a plant of the nature and size of this one, 22,500,000 ft.-lbs. probably represents about as high a degree of economy as can be expected, although under more favorable conditions, with higher pressures and larger volumes, it is quite possible that 30,000,000 or even 35,000,000 might be reached.

The air-lift equipment of the wells is stated by the Pneumatic Engineering Co. to be as follows:

Well No.	Diameters, Inches			Max. Lift	Submergence.
	Well.	Discharge.	Air.	ft.	ft.
1	10	4	1	33	44
3	10	5¼	1¼	26	40.8
4	10	4½	1	28	47
5	10	4½	1	28	47
6	10	4¾	1¼	26	49
7	10	4½	1	30	45
8	10	4¾	1¼	28	45
9	10	4	1	33	44.2
10	10	4	1	40	37
11	10	4	¾	40	*30
12	4½	4½	1	..	..

[*Discharge pipe 20 ft. below inlet.]

Note.—These wells have outside air-pipes except Nos. 11 and 12, which have inside air-pipes. No. 12 is pumped in the casing direct.

The two wells sunk subsequent to the above tests use the casing itself as discharge pipe. They have the following dimensions:

Well No.	Depth, ft.	Diameter, Ins. Well.	Air-pipe.	Strainer.
2	196	6	1½	40 ft. Coarse Cook.
13	96	10	2½	30 ft. Cook; 20-ft. gauze 45 ft. below surface.

These wells, like the others, are pumped with 33 lbs. pressure, and have similar depths of submergence. The delivery of the 13 wells now equipped reaches about 5,450,000 gallons per 24 hrs.

EXPERIMENTAL STUDY OF AIR-LIFTS.

The questions of the interrelation of depth of air-pipe, lift, size of discharge pipe, etc., were studied recently in an extensive series of experiments by the Westinghouse Air Brake Co. The experiments were all made in a 6-in. well, 174 ft. deep, near the company's plant at Wilmerding, Pa. The water-level in this well is normally 16 to 20 ft. below ground surface. The results and conclusions of the tests are stated in general terms in a circular prepared by the company, but no numerical data or curves showing the variation of discharge, air-consumption, etc., with changes of the several factors, are given, and on inquiry the company states that it is not prepared to give out such data at the present time. Only description of the method or experimenting and a statement of the general nature of the results can therefore be given.

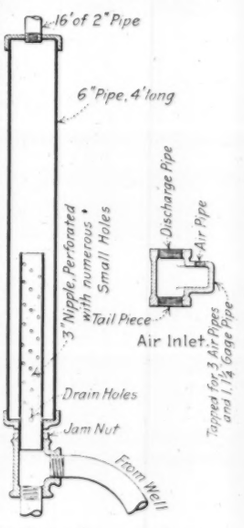


Fig. 1. Foot-Piece and Head-Piece Used in Westinghouse Air Brake Co.'s Air-Lift Experiments.

To provide for varying the lift, the following arrangement was used: An oil-well derrick was built over the well, with platforms at different heights. The discharge-pipe was run vertically from the well to some one of these platforms, and here the air-separator head, shown by Fig. 1 herewith, was mounted on the pipe. The base of the separator defined the height of discharge. In operation the air liberated from the discharge passed up into this separator and out to atmosphere by a 2-in. pipe, while the water flowed down through a 3-in. pipe to a three-way cock which directed it into either one of two weighing tanks set in a shelter cabin built around the well head.

The well was used only with separate discharge pipe, i. e., no tests were made using the well-casing itself as discharge pipe, because the well was of insufficient capacity for this. Different sizes of discharge pipe were used, "from the smallest practicable to the largest possible, considering the capacity of the well." The air-pipes were in all cases outside the discharge pipe. To save space in the well, several small air-pipes were used instead of one larger one, and this permitted varying the effective size of air-pipe by simply closing one or more of the pipes.

The foot-piece had the form shown in Fig. 1. The air-pipes and a 1¼-in. gage-pipe, which by a gage at the top measured the pressure of the air at entry into the well, were screwed into the top of the lateral chamber, while the discharge-pipe itself screwed into the top of the main body. Generally the discharge-pipe was prolonged downward below the air-inlet casting to form a tail-piece, in order to prevent loss by air blowing out of the bottom of the foot-piece.

The air supply was obtained from a 1-in. connection to the 140—160-lb. air system of the Westinghouse Air Brake shops. The arrangement of piping, reservoirs, etc., is shown diagrammatically in Fig. 2. Two air storage reservoirs, 30½ × 84 ins., received air from the supply through a three-way cock, so that only one tank could be charged at a time. At the other end of these tanks, connection was made through a similar three-way cock to the line to the well. In this line was placed a 14 × 33-in. equalizing reservoir, a globe-valve and a cut-off cock, the globe-valve being used to regulate the air-pressure delivered to the well, which of course was always less than the supply pressure and had to be held constant. Tank No. 2 was used for measuring the air in the tests, and Tank No. 1 for starting the pumping operation. The volumes of the tanks and the piping was obtained by water measurements. A special test gage was attached to Tank No. 2, by which the pressure in the tank was read at the beginning and the end of each test, taking care to let the tank assume normal temperature before reading the gage. The air-supply pipe being closed during a test, the volume of air delivered to the well could be computed from the known volume and the initial and final pressures.

The height of the water surface in the well was measured by a float consisting of a small closed tin tube, about 4½ ft. long, weighted at the lower end to float upright, and pointed at both ends for easy introduction into and withdrawal from the well. A cord attached to the top of the float, with markers attached every 4 ft., enabled the depth to water level to be read conveniently at all times. The lengths of the piping being known, two important quantities could be found: (1) the lift, or the height from water surface to top of discharge-pipe, and (2) the submergence, or depth from water surface to air inlet.

The series of tests, it is said, comprised nearly 1,800 different experiments covering nearly 400 different combinations of discharge pipe diameter, lift and submergence. The following is a general statement of what these tests showed:

1. The rate of delivery of water, and the air-consumption per gallon, with fixed size of discharge pipe, are practically constant for all lifts, provided the ratio of lift to submergence is maintained constant.

2. With a discharge-pipe of given diameter, the delivery decreases and the air-consumption per gallon increases as the ratio of lift to submergence increases.

3. With a fixed ratio of lift to submergence, the air-consumption per gallon decreases as the size of discharge-pipe increases.

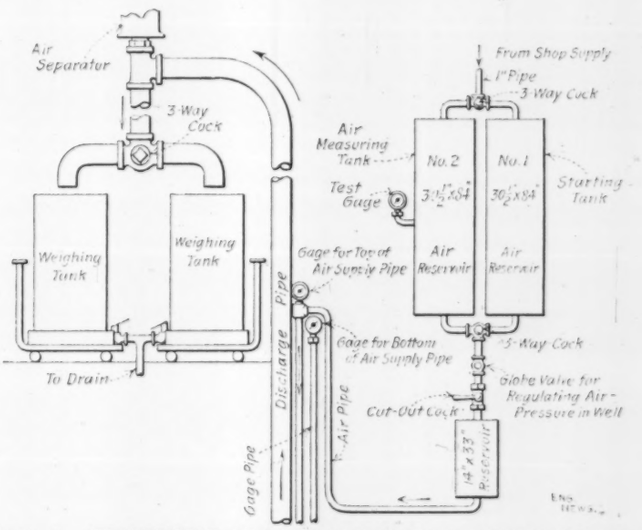


FIG. 2. ARRANGEMENT OF MEASURING TANKS AND PIPING IN AIR-LIFT EXPERIMENTS.

4. The least air-pressure that will give continuous flow is the proper pressure to use. A slightly lower pressure gives intermittent delivery, and the amount delivered is much decreased, though the air-consumption per gallon is slightly lower than with continuous flow. With pressure higher than just enough to give continuous flow, the delivery is increased somewhat, but the air-consumption per gallon delivered is increased in greater ratio; and with further increase in air-pressure a point of maximum delivery is reached, beyond which the delivery is *decreased* in amount. The sound of the discharge is a reliable guide to proper regulation of the air-supply.

5. It appears from (2) that by increasing the submergence, i. e., locating the foot-piece deeper down in the water, for a given lift, the air-consumption is progressively reduced. But as the required air-pressure is increased with the greater depth, a cubic foot of air represents greater power. A curve representing the variation of horsepower required per gallon of water delivered, with depth varying, shows that the power first decreases with increasing depth, then reaches a minimum and thence increases. The ratio of lift to submergence at this minimum point may be called the "economical ratio."

6. For a given size of discharge-pipe the economical ratio decreases as the lift increases; i. e., the submergence should be increased in greater ratio than the lift. For a given lift, the economical ratio increases (submergence decreases) as the size of discharge-pipe increases.

7. A tail-piece, or projection of the discharge-pipe below the air-inlet, is essential in starting, as it tends to prevent the air from backing down into the well and rising in the casing outside the discharge-pipe.

8. Anything in the shape of a jet or pipe introduced into the discharge-pipe to serve as air-inlet has no value, and is, in fact, detrimental by forming an obstacle to the free passage of water. The fitting used as air-inlet as shown in Fig. 1 was particularly well adapted to its purpose, and had the further advantage of making it possible to install the air-pipe very close to the discharge-pipe.

9. The size of air-pipe is determined only by considerations of friction-loss required to force the air through the pipe.

10. In starting the pumping, the air should be admitted slowly. Pumping will not commence immediately, but after several seconds, perhaps even a minute, water will come with a rush. This is followed by a lull, after which the operation becomes more uniform. The valve can then be opened until continuous flow is obtained.

The last given information was derived from observation of a glass model of a deep well, made for exhibition purposes. This model showed also that the layers of water, which rise in the discharge-pipe under the impulsion of the layers or bubbles of air, lose water by a slipping back which goes on along the sides of the pipe, water slipping in this way from each layer past the intervening air to the next. Any change in diameter of pipe, as at couplings or joints, increases the slip, and obstructions or sharp bends similarly add to the loss.

The bodies of air in the discharge-pipe, it was observed, are not clear, but are filled with bubbles and foam, whereas the bodies of water are clear or distinct. Whether this observation applies to all rates of delivery, all sizes of discharge-pipe, etc., is not known.

PROGRESS OF EXCAVATION ON THE PANAMA CANAL.

In our issue of Feb. 13, 1908, p. 170, we published a statement of the Isthmian Canal Commission showing the progress of excavation on the Panama Canal up to Feb. 1, 1908. With the article there was included a diagram, similar to those shown herewith, which illustrated the proportion of the work done to the estimated total necessary excavation of 124,334,856 cu. yds. At that time there had been excavated 25,467,859 cu. yds.; since then the recently adopted plan changing the location of the locks at La Boca to Miraflores and constructing a sea-level channel between those points, has added about 18,000,000 cu. yds. to the total estimated excavation, making the total required to be excavated from May 1, 1904, 142,000,000 cu. yds.

The Isthmian Canal Commission has issued a new statement of the progress of the work which changes slightly some of the detailed figures

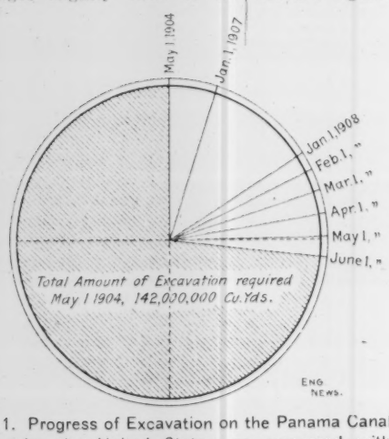


Fig. 1. Progress of Excavation on the Panama Canal under the United States, as compared with total excavation required.

given in our previous summary and also differs in some cases from the monthly reports which the Commission has been issuing. These discrepancies in amounts are not large enough to affect results, but will explain the lack of exact agreement between this and previous statements. Up to Jan. 1, 1908, the total excavation under American occupation was 22,756,486 cu. yds., or 16.0% of the total; during the first five months of 1908 the excavation was 15,124,045 cu. yds., bringing the total on June 1, 1908, up to 37,880,531 cu. yds., or 26.65% of the total. These latter items are tabulated as shown in the table at the bottom of the page.

In the accompanying figures are shown graphical representations of the stage of excavation progress. Fig. 1 shows the relation of the American yearly and monthly excavation to the total anticipated American excavation, 142,000,000 cu. yds. Fig. 2 takes into account the 40,200,196 cu. yds. French excavation. Adding this amount to the estimated American total, a total of 182,000,000 cu. yds. will be required to be excavated, figuring from the beginning of the work until its completion. Of this amount the French did 22%, the Americans have already done 21%, and there remains to be done 57%.

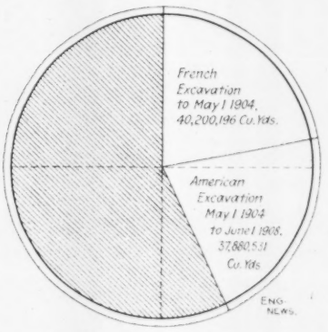

French Excavation to May 1 1904, 40,200,196 Cu. Yds.
American Excavation May 1 1904 to June 1 1908, 37,880,531 Cu. Yds.
ENG. NEWS.
Total Estimated Excavation,—including French,—182,000,000 Cu. Yds.

Fig. 2. Diagram Showing Relation of French and American Excavation on Panama Canal to Total Estimated Amount.

TUNNEL BREAKAGE, OUTSIDE OF PRESCRIBED CROSS-SECTION; CLINCH VALLEY DIVISION, NORFOLK & WESTERN RAILROAD.

By EMILE LOW,* M. Am. Soc. C. E.

In Engineering News for April 30, 1908, there appeared an article on the "Section Overbreakage in Gunnison Tunnel, Colorado," which is of more than passing interest. Outside of some articles published in Engineering News (June 9, 1892, p. 574, April 19, 1900, p. 257) by the writer, on this subject, he knows of no other published data.

The usual practice is not to pay for any tunnel excavation outside of the prescribed cross-section; in fact, many specifications state so in so many words. Others leave a loophole covered by the clause "slips or falls will be paid for when not caused by the fault of the contractor." This throws the decision on the engineer and he may not always give a satisfactory one.

In order to add to the literature of the subject, the writer has been to some trouble to collate some information regarding tunnel breakage on the Clinch Valley Division of the Norfolk & Western Railroad. [See Eng. News, June 9, 1892, for a description of tunnel work on this line, by Mr. Low.—Ed.] There are ten tunnels (all single track) on the line of this railroad, ranging in length from 155 to 1,925 ft. and with a total length of 9,105 ft.

Tunnels 1, 2 and 3 and also the Honaker tunnel are driven through limestone, the remainder through shale and sandstone, small coal veins intervening in some of them, especially in Big Bull tunnel.

The price to be paid for a cubic yard of excavation was fixed by the railroad company at $3.25 for tunnels less than 1,000 ft. long and $3.50 for tunnels over that length. At the time of letting the contracts, it was believed that no timbering would be necessary, but upon driving the tunnels it was found that this protection was needed in some.

In the region traversed by this railroad, namely Southwestern Virginia, the formations are badly faulted, strata 2,000 ft. apart geologically being found in close contact. This faulting gives rise to abnormal cleavage, with segregation of clay bands to an extent not found under other circumstances. On account of the geological structure, landslides are of frequent occurrence. Fig. 1, which is a photograph of the west portal of No. 1 tunnel, shows the inclination of the strata very plainly.

The inclination at the east portal of the Honaker tunnel is still steeper, being not far from 45 deg.

The formation at these tunnels is limestone rock. Referring now to the accompanying table, which gives the details of all the tunnels, we note that the breakage of Nos. 1, 2, 3 and Honaker tunnels, ranges from 16 to 24%, the average for the four being 21%. The breakage is wholly caused by the inclination of the strata, and is shown graphically by Fig. 2, which is a cross-section of one of the tunnels. The cross-section shown is for a tunnel on a tangent. Where the alinement is on a curve the cross-section is somewhat larger.

Kiser tunnel is driven through a shale rock, and the excessive breakage (44%) was caused by large falls from the roof, near the east portal. At Creagan tunnel the percentage of breakage is also above the average, being 34%. The material in this tunnel is slate at the east end and sandstone at the west end.

At Big Bull tunnel the material driven through is slate rock, with the exception of a short distance at the east end, where the material is clay. In driving this tunnel several seams of coal were encountered. The breakage here is 23%, due mainly to falls. Little Bull tunnel adjoins Big Bull and the conditions are almost identical.

The material encountered in Holbrook tunnel is slate at the east end and sandstone at the

Fig. 1. West Portal, Tunnel No. 1, Clinch Valley Division, Norfolk & Western R. R., Showing Inclination of Strata.

west end. The slate is overlaid with a harder rock, and also rises to the west. In driving the heading the slate separated from this harder rock, causing a large increase in the height of the heading, which at the highest point reaches a height of 17 ft. above the tunnel roof, the tunnel having a total height of 37 ft. above the bottom grade. Much of the breakage here, 32%, is attributable to the falls of slate at the east end.

Little Tom tunnel is driven through slate and sandstone, the former at the west end and the latter at the east end. The sandstone forms the roof and floor of the coal seams found in the vicinity of the tunnel. The strata lie approximately level and vary from a few inches to several feet in thickness. The breakage here is 25%, due largely to the laminations of the sand-

*606 Ashland Avenue, Buffalo, N. Y.

1908.	Culebra division by steam shovel from canal prism.	At other points by steam shovel from prism.	By steam shovel outside prism.	Dredging in canal prism.	Dredging outside prism.	Total.
January	1,150,334	433,052	175,276	904,653	46,298	2,709,613
February	1,176,752	480,729	178,404	1,065,406	25,835	2,927,126
March	1,216,264	689,169	251,687	1,298,594	31,663	3,487,287
April	1,170,872	696,589	255,730	1,172,905	.....	3,296,096
May	930,179	501,219	177,673	1,094,852	.....	2,703,923

stone, causing large pieces to flake and fall from the roof.

In driving the tunnels hand drilling was almost universally employed, although some machine drills operated by compressed air were used in Big Bull and Little Tom tunnels.

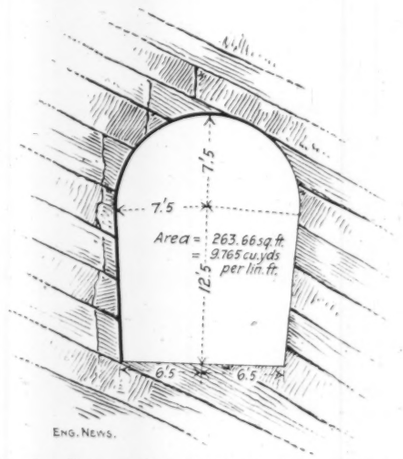


Fig. 2. Cross-section of Tunnel, Showing Inclination of Limestone Strata.

It was early recognized that under ordinary conditions of working some breakage was unavoidable and so should be paid for. The price was fixed at $1.50 per cu. yd., and applied to every one of the ten tunnels driven. In nearly every case the extra material was utilized, either in the adjacent embankments or was placed into spoil banks and afterwards used for ballast.

The method of determining the quantities of breakage was almost identical with that used on the Gunnison tunnel, measurements being taken from the backs of the timbers of the timbered portions of the tunnels. In the rock sections various methods were employed, generally depending on the fancy of the resident engineer in particular charge, there being a number of these. The measurements were all plotted to scale, and the areas calculated, not planimetered.

TABLE SHOWING OVERBREAKAGE IN TUNNELS ON THE CLINCH VALLEY DIVISION OF THE NORFOLK & WESTERN RAILROAD.

No. or name of tunnel.	Geological formation.	Length, feet.	Cubic yards—Regular section.	Cubic yards—Breakage.	Per cent of breakage.
No. 1	Limestone	155	1,514	288	19
No. 2	Limestone	437	5,252	821	16
No. 3	Limestone	541	6,126	1,467	24
Honaker	Limestone	1,054	10,434	2,248	22
Kiser	Shale	500	6,300	2,759	44
Creagan	Slate and sandstone	905	11,287	3,850	34
Big Bull	Clay and slate	1,695	20,835	5,818	23
Little Bull	Slate	327	4,498		
Holbrook	Slate and sandstone	1,566	17,318	5,477	32
Little Tom	Sandstone and slate	1,925	21,430	5,322	25
Totals		9,105	104,994	28,050	27

AERIAL PHOTOGRAPHY FOR TAKING BIRD'S-EYE VIEWS OF INDUSTRIAL PLANTS.

The use of cameras attached to kites for taking bird's-eye views from great heights has been applied in a number of cases for military, survey and other work, and an example of such a photograph is shown herewith. It was made by the George R. Lawrence Co., of 1368 Broadway, New York. The aerial photographic apparatus used is composed of (1) a series of aeroplanes by means of which it is elevated to the necessary height; (2) the controlling device by which the camera is held rigid in the air during the time the exposure is being made, and (3) the electrical device for making the exposure. The aeroplanes are each 8 ft. square, and have a wind surface of 60 sq. ft. It is usual in making exposures at an altitude of 1,000 ft. to use from 12 to 18 of these. They are sent up one after another, dragging a cable until the lifting force is great enough to carry the combined weight of 3,000 ft. of cable and the camera with its electrical appliances.

When the camera is 1,000 ft. high, the top aeroplane is 3,000 ft. high, or practically out of sight. The lowering apparatus is operated by a 3 HP. gasoline motor. The man who makes the picture watches the camera with a strong field glass, and must keep his eyes upon the apparatus high above. He has his finger upon a switch, which controls the electrical device for making the exposure. It may require from one to three hours before the right moment arrives to press the button. The instant the shutter is released, a miniature parachute escapes from the apparatus, indicating that the exposure has been completed. The apparatus can then be lowered.

The view shows the two plants of the Universal Cement Co., at Buffington, Ind., 22 miles from Chicago, near Lake Michigan. The plans adjoin each other and form practically one large plant, but they were built at different times, and are operated separately.

The plant in the foreground was started on Jan. 1, 1905. It contains 16 kilns, 90 × 7 ft., and has a daily output of 5,000 barrels. The stockhouse has storage room for 310,000 barrels. The other plant was started on Oct. 27, 1907. It contains 12 kilns, 120 × 7½ ft., and has a daily output of 6,000 barrels. The stockhouse is one of the largest in the country, being 560 × 100 ft., and holds 400,000 barrels. Both plants are operated entirely by electric power, generated by waste gases from the blast furnaces of the Illinois Steel Co., at South Chicago, and transmitted by means of high tension alternating-current which is transformed at the plants for distribution.

AERIAL PHOTOGRAPH OF THE PLANT OF THE UNIVERSAL CEMENT CO., BUFFINGTON, IND.

(Copyright by the George R. Lawrence Co.)

SMOKE ABATEMENT IN CHICAGO.

The smoke problem in Chicago is being taken up on an educational and economic basis by the cooperation of various commercial and technical interests. It is hoped in this way to effect greater improvement than by the mere warning and fining of owners of buildings or plants whose smoke is more or less of a nuisance. A smoke abatement meeting was held May 5, being composed of representatives of the Illinois Coal Operators' Association (which has a coal-stoking and anti-smoke committee), the Chicago Smoke Abatement Commission, the Western Society of Engineers and the City Smoke Inspection Bureau.

The coal operators' association is naturally inclined to take the part of the consumers, who form its customers, especially as it has been rumored that the smoke-abatement commission proposed to advocate the introduction of semi-bituminous coals from sources outside the State. It was explained at the meeting, however, that the commission did not advocate such a step (except in some special cases), but expected to secure the smokeless combustion of Illinois coals. It may be noted in this connection that the engineering experiment station of the University of Illinois has made an investigation of this matter, and has issued a bulletin dealing with methods and appliances for burning Illinois coal without smoke. The city Smoke Inspector explained that suits based upon smoky conditions are now brought only when the offenders seek to antagonize the efforts of the city to secure better conditions. As a result of the conference, the coal operators' association agreed to co-operate

with the other bodies in promoting measures for the suppression of smoke, because it is realized that the Illinois coal industry will be benefited if consumers more generally understand that this coal may be burned without objectionable smoke.

One coal operator, however, took a decidedly different and quite erroneous position. He argued that it is impossible to burn bituminous coal without smoke, and that to enforce laws prohibiting smoke is an injustice to the public, the coal operators and the consumers. The principal reply to such an argument is that by the use of proper furnaces and methods of firing, bituminous coal certainly can be burned without objectionable or excessive smoke, and it is the smoke due to the lack of such appliances and methods that has given rise to the demand for the suppression of smoke.

While no definite action was taken at the meeting, it was the almost unanimous opinion that the facts as to coal combustion and smoke prevention should be given the widest possible publicity, and that this work should be directed by a joint committee of the three associations mentioned above. The steps proposed to be taken are outlined as follows:

1. Attention should be called to the importance of the personal equation of the fireman as a cause of smoke.

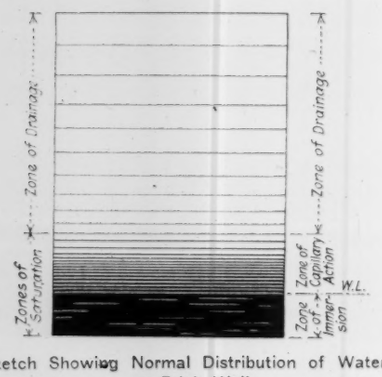
2. The degree of influence which coal has on smoke should be made clear for the information of coal users. This appears to be a feature of very great importance, because consumers often believe that by changing the dealer or the source of supply they will get a product that makes less smoke. This practice causes much confusion and trouble without producing any beneficial result. Thus the fireman may say that the coal is bad and of a smoky character, when in reality it may be the fault of the man who improperly manipulates the fire.

3. The importance and desirability of the use of a better class of furnace apparatus should be definitely and decidedly emphasized. In this connection an effort should be made to produce in the mind of the general public a realization of the fact that there is a difference between apparatus which will not make smoke if carefully manipulated, and one which will be smokeless under any condition of operation. The development and installation of the latter character of device is most desirable.

ELECTRIC MINE LOCOMOTIVES in the anthracite coal regions have within three years, i. e., 1903-1906, increased from 84 to 205; compressed air locomotives increased from 67 to 104 during the same period, while the number operated by steam decreased from 49 to 41. One of the primary causes of the increase in mechanical haulage is the extension of the mines and consequent increasing length of underground haul.

ADVANTAGES OF POROUS BRICK IN BRICK WALLS.

In freezing tests for brick there is a rarely recognized factor to which Mr. J. C. Jones, in Vol. IX., Transactions American Ceramic Society (Edward Orton, Secretary) draws attention. The distribution of water in brick walls is normally such that certain classes of brick, which



Sketch Showing Normal Distribution of Water in a Brick Wall.

are frequently condemned for their porosity, are logically the best possible material for definite parts of the structure. In the accompanying sketch the foundation is shown as below the water line and in a constant state of immersion: here it is true, the question of pore space is paramount. No drainage is possible. This is the place for the bricks that have been burned hardest, the effective diameter of the pores having thereby been so decreased as to offer the greatest resistance to the flow of water.

A second effect of greater hardness is increased tenacity in opposition to the expansion of forming ice. No damage to brick can be caused by ice except at the time of its formation as the coefficient of expansion of clay wares is .00000457, while that of ice is .0000350, the resulting contraction of the latter being therefore nine times as rapid as that of the former; when the temperature is lowered the ice shrinks away from the walls of the pores.

Coming to that portion of the wall just above the water line we find the amount of water dominated by the influence of capillarity. The finer pored the brick is, the higher will be the ascension of water, yet, the condition being that of saturation, the possible advantages of a lower water level attending the use of coarse brick is overcome by the greater strength inherent to fine pored material. In the upper part of the wall, however, constituting much the largest zone, exists a possibility of complete drainage. Water can be precipitated here only on the outer surface by atmospheric and mechanical agencies, and the best material from the point of view assumed in the freezing test is evidently that which will most readily pass off the water, i. e., the coarse pored brick.

TRANSPLANTING AN 80-FT. TREE WITH A LOCOMOTIVE CRANE.

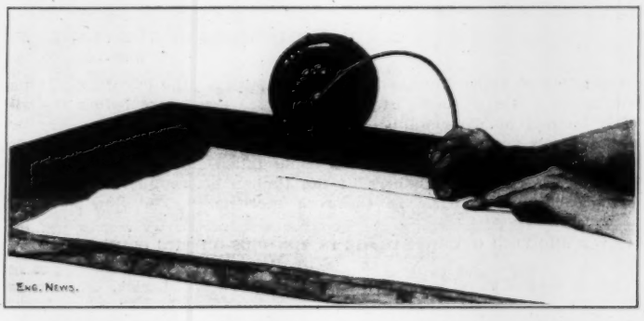
What might be strained into a form of "conservation of natural resources" is illustrated by the accompanying figure. This shows an oak tree some 80 ft. in height and about 18 ins. in diameter, with a ball of earth and roots 15 ft. across, being carried from one part of the works yard of the Crocker-Wheeler Co., at Ampere, N. J., to another. In the course of extensions of the present plant it became necessary to build the factory tracks over the place where this tree, among others, had grown. As much attention had been paid to laying out the improvements and extensions of the plant with regard to future landscape effects it was desired to transplant these trees rather than destroy them. From trials with similar small trees the best place to grasp the tree, after freeing the roots from the holding soil, was ascertained. The tree was lifted out of its old place, carried by the locomotive crane several hundred feet along the track and deposited,

TRANSPLANTING AN 80-FT OAK AT THE WORKS OF THE CROCKER-WHEELER CO., AMPERE, N. J.

always maintaining the vertical position shown. The bark was protected by burlap and the wrappings were thrown around the tree and through the crane hook. A large block offset was found necessary to hold the tree upright against its uneven distribution of weight.

A MOTOR-DRIVEN ERASER.

In large drafting rooms of manufacturing plants where many and extensive changes on tracings are necessary the erasing becomes irksome work, and the time consumed may become excessive. The idea shown in the accompanying figure is not new, but this is believed to be the first time such apparatus has been placed on the open market. A small 1-12 or ⅛-HP. Westing-



A MOTOR-DRIVEN ERASER. MADE BY THE COATES CLIPPER CO., WORCESTER, MASS.

house motor drives the eraser through a flexible shaft. Good results should be obtained by using a soft wheel and feeding powdered pumice stone to the tracing. The outfit is made up by the Coates Clipper Co., of Worcester, Mass.

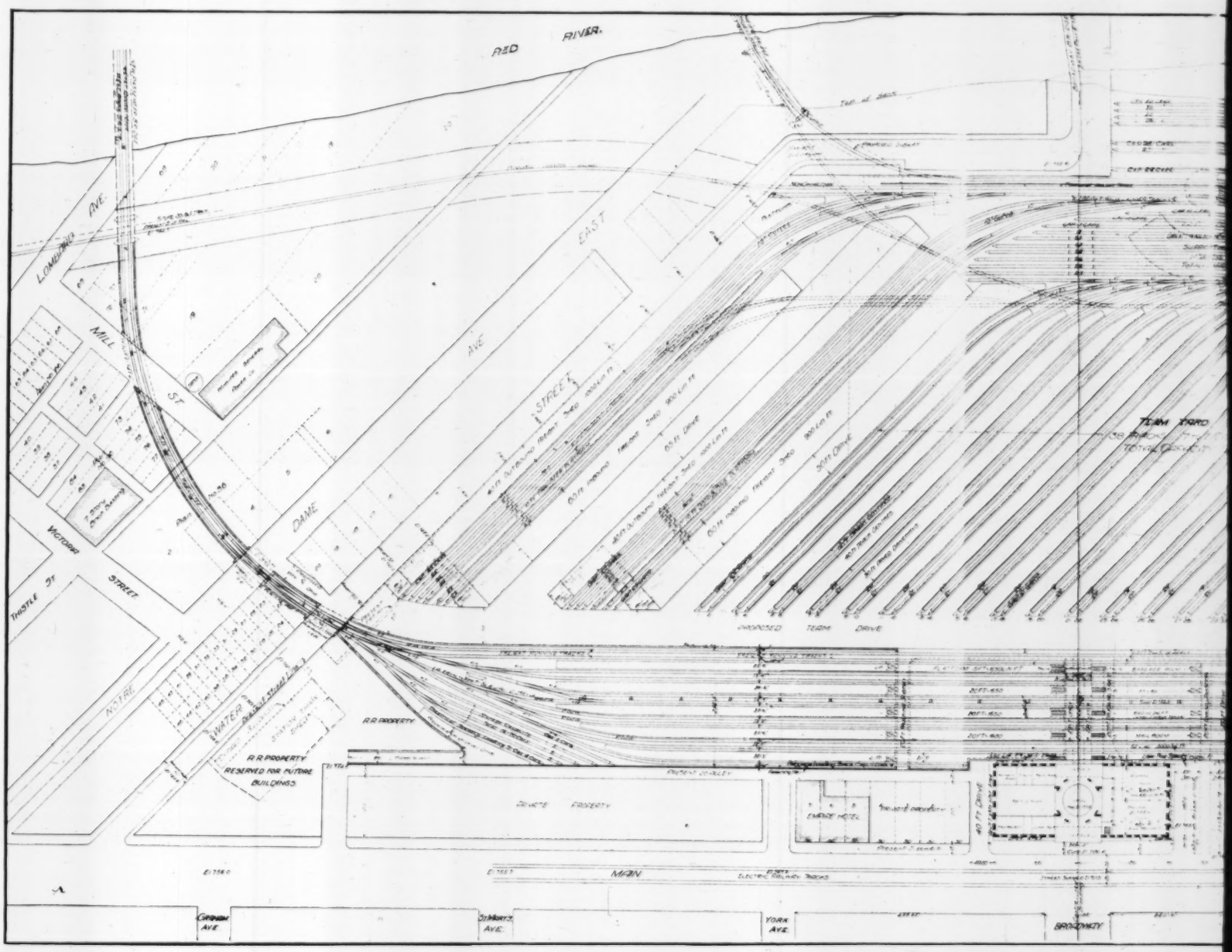


FIG. 2. GENERAL PLAN OF TER

TABLE OF CAR CAPACITIES

Passenger Yard	Platform Tracks	188	70-ft. cars	Freight
	Baggage and Express Tracks	27	70-ft. cars	
	Coach Storage	28	70-ft. cars	
	Total Passenger Tracks	243	70-ft. cars	

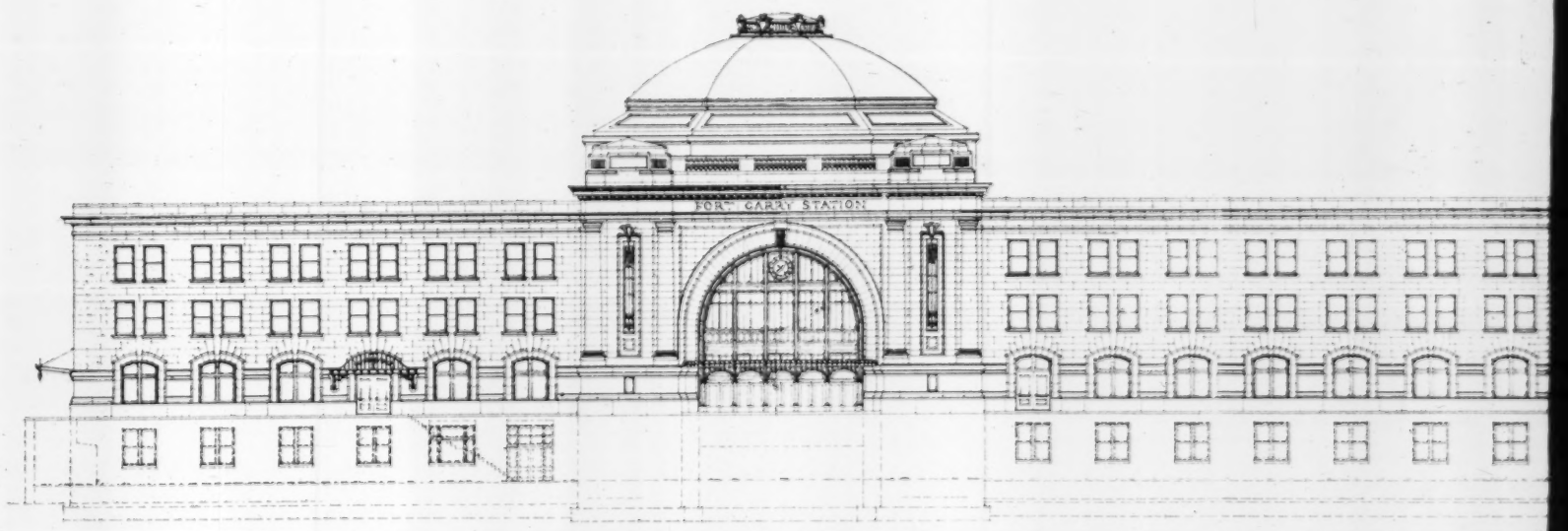
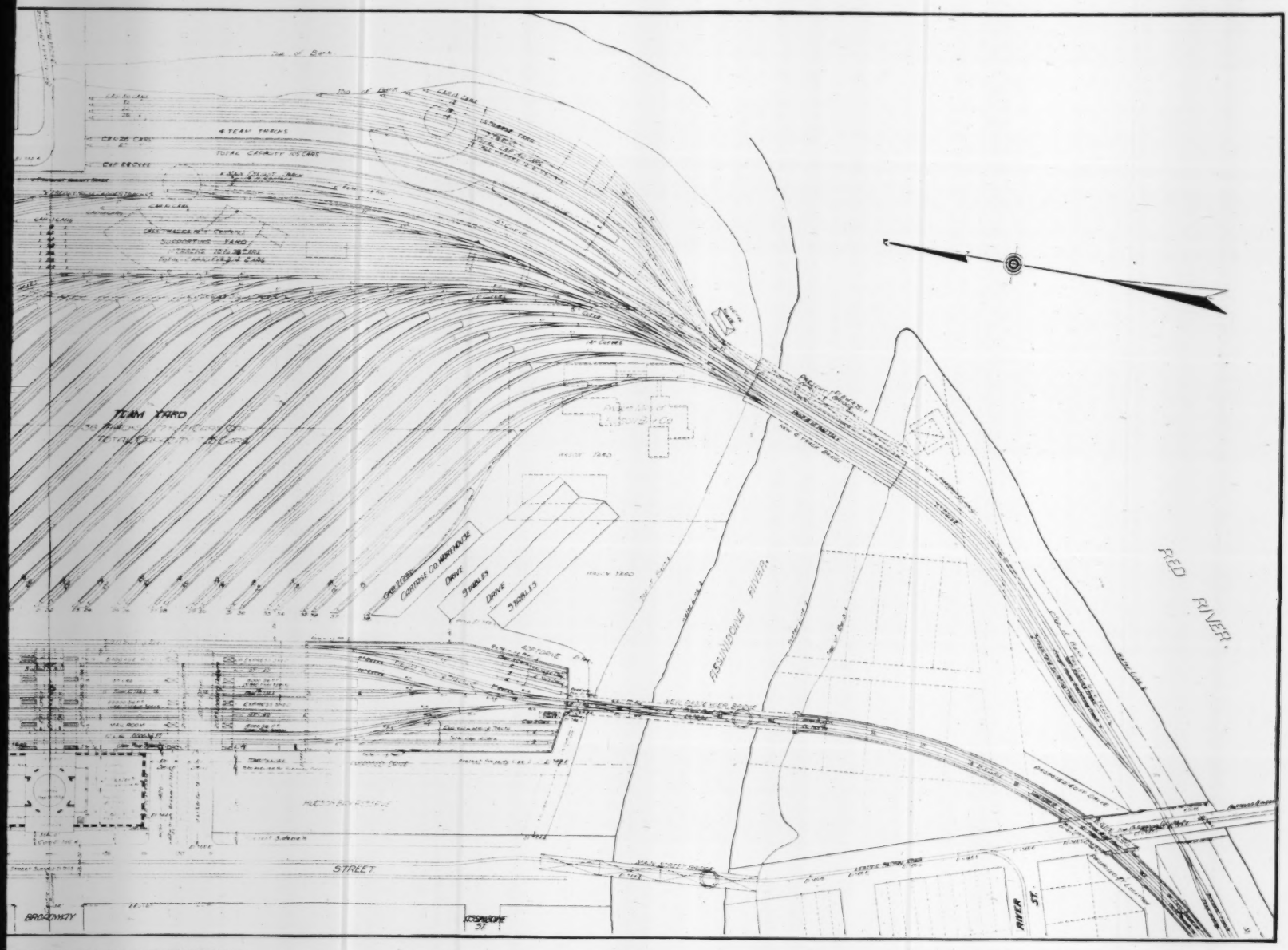


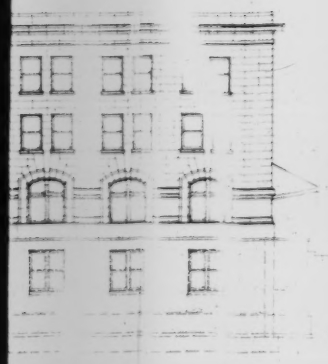
FIG. 3. FRONT ELEVATION OF STATION BUILDING.



GENERAL PLAN OF TERMINAL.

ABLE OF CAR CAPACITIES.

70-ft. cars	Freight Yard	Team Tracks	830	40-ft. cars
70-ft. cars		Supporting Tracks	354	40-ft. cars
70-ft. cars		Freight-House Tracks	288	40-ft. cars
70-ft. cars	Total Freight Tracks		1,472	40-ft. cars



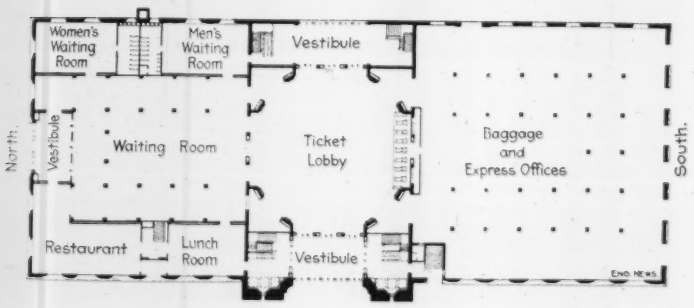


FIG. 4. PLAN OF MAIN FLOOR OF STATION BUILDING.

THE NEW FORT GARRY TERMINAL AT WINNIPEG, MAN.

Canadian Northern Railway.
Grand Trunk Pacific Railway.
National Transcontinental Railway.

Designed by
WARREN & WETMORE,
Architects.

ENGINEERING NEWS

A Journal of Civil, Mechanical, Mining and Electrical Engineering

Published every Thursday by

THE ENGINEERING NEWS PUBLISHING CO.

220 BROADWAY, NEW YORK

BRANCH OFFICES

CHICAGO: 1636 Monadnock Block
WASHINGTON, D. C.: Home Life Building
ATLANTA: Candler Building
RUDOLPH MOSSE, BERLIN AND HAMBURG, GERMANY
Z. P. MARUYA & CO., Ltd., TOKYO, JAPAN

GEORGE H. FROST, President
CHARLES WHITING BAKER, Vice-President
HARWOOD FROST, Secretary
FRANCIS W. FROST, Treasurer

ALFRED E. KORNFELD, Manager
EDWIN HUNT FROST, Ass't Manager

CHARLES WHITING BAKER, M. N. BAKER, E. E. R. TRATMAN, F. E. SCHMITT, } Editors

SUBSCRIPTIONS

United States and Possessions, Mexico and Cuba, One Year, $5.00.
Canada, $7.00 a Year.
Foreign Countries, Regular (Thick Paper) Edition, One Year, $9.00. (£1-18-0.), 45 Francs or 37 Marks.
Foreign Countries, Thin Paper Edition (Construction News Supplement Omitted), $7.00. 29 Shillings, 35 Francs or 29 Marks. Remit directly to our office.
Pay no money to canvassers for subscriptions.
Remit by Post-Office or Express Money Order, Draft on New York or London, or by Registered Letter.
Notice of change of address should reach us one week in advance of removal. The old as well as the new address should be sent.
Subscriptions cannot be dated to commence with past issues. All subscriptions commence with current issue and back numbers can be supplied only by special order.
Receipts for Subscriptions will not be sent unless requested, the changing of the expiration number being considered sufficient. The number on the address label indicates when subscription expires, the last figure indicating the year and the one or two preceding figures the week of that year. 52-7 means the 52d week or December 26, 1907.

ADVERTISING

"Contract": Rates furnished on application.
"For Sale": $1.50 per inch.
"Proposal": $2.40 per inch.
"Want": See "Want" Pages.

Copy for regular, or "Contract," Advertisements should be received at least ten days before publication; "For Sale" and "Situations Wanted" Advertisements by Monday, and "Proposal" and "Situations Open" Advertisements by 9 A. M. Wednesday.

Entered at the New York Post-Office as Second-Class Matter.

Why is water deposited in a compressed air reservoir? How much water will collect in a reservoir in a given time, with air supply of a certain degree of humidity and a compressor of a given size run at a certain speed?

We doubt very much whether any considerable proportion of engineers experienced in compressed air work could give a clear answer to these two questions. That more or less water is deposited in compressed air pipes, and that it makes trouble by freezing up in cold weather and by clogging with ice the escape ports of compressed air machines is well known; but there appears to be too little knowledge of what to do to remedy the trouble, or at least too much carelessness and neglect in the application of that knowledge.

On another page of this issue we print the most practical and useful paper on moisture in compressed air that has ever appeared, so far as we are aware, anywhere in engineering literature. While the paper relates primarily to moisture in air brake, signal and interlocking systems, it deserves study by everyone who has to do with compressed air work in shop, mine or field.

The author of the paper, Mr. Murphy, shows clearly that water is *always* present in a compressed air system; and that it is just as certain that water will be deposited from compressed air when it cools as it is that it will drip from a wet sponge when squeezed.* The lesson is that provision should be made for the regular and systematic removal of water from every compressed air system, and this should be attended to as regularly and carefully by the operator as the oiling of the compressor cylinder. In cases where such attendance cannot be assured, it is worth consideration whether some simple automatic means might not be devised for discharging the accumulated water from the reservoir at regular intervals.

Again, most writers assume the ratio of the weight of a cubic foot of saturated steam to a cubic foot of pure dry air, at the corresponding pressure and temperature, to be constant at approximately 0.622. Mr. Murphy's study shows that, for a range of temperatures from −30° to + 434° F., the actual value ranges from 0.6082 to 0.7073, respectively, and that the value of 0.622 holds only for the immediate vicinity of 90° F.

The table which is given in the paper should be of much practical value to engineers who have to do with problems in connection with drying apparatus, humidifiers and other machinery in which the moisture content in air becomes of importance.

*The only possible exceptions are compressed air systems working in exceptionally dry climates, such as southern Arizona, or compressors working at very low pressures. Here it is possible at times that the final temperature and pressure of the compressed air may not exceed the point of saturation.

The proverbial Scotch verdict "Not proven" appears to have been the result of the second criminal trial for conspiracy of those who were concerned in the looting of the Pennsylvania state treasury through the contracts for furnishings.

In the trial last spring, John H. Sanderson, who had the contract for "trimming" the Harrisburg capitol, and three ex-state officers, ex-Auditor General William P. Snyder, ex-Treasurer William L. Mathues and ex-Superintendent of Grounds and Buildings James M. Shumaker, were convicted of conspiracy to defraud the state. In the trial just concluded, the same three state officials, with Congressman H. Burd Cassell, who had a contract for metallic furniture, and Joseph M. Huston, the architect of the capitol, were tried for conspiracy to defraud in connection with a certain invoice for metallic furniture amounting to $17,789. The judge directed the acquittal of the three ex-state officers in this case, on the ground that the evidence presented was insufficient to show that they had conspired to defraud the state on this particular bill. The jury acquitted Cassell and Huston presumably on the same ground.

We make no pretence of expressing an opinion as to the technical grounds on which a verdict of "not guilty" was given in this particular case, except to say that its actual meaning is, only, as we have pointed out above, "not proven." A man may be in the eyes of the law considered innocent until he is proved guilty; but in the eyes of the public the men who looted Pennsylvania of some eight million dollars in the contracts for furnishing the state capitol are guilty, even though it were found impossible to establish in court the exact way in which they conspired together to carry out the robbery.

The widespread damage by floods in the territory west of the Mississippi River during the past three weeks ought to direct renewed attention to the need for more systematic and intelligent river improvement engineering in this country.

We do not mean by this to advocate specifically the reservoir system or any other system of control. In fact over a large part of the region between the Mississippi and the Rockies the probabilities are that nothing in the way of a reservoir system would be possible on account of lack of sites for economical reservoir construction.

What we would urge is that all work on our rivers should be done with a view to general conditions as well as local conditions. Cities have built levees and training walls along the course of a river within their limits and have had so much in view the saving of all the land possible along the water front that they have narrowed the channel and diminished its flood capacity.

Again in locating bridges, such as those over the Kaw River at Kansas City, the tendency has been to keep down the cost of approaches and the cost of operating over approach grades, by steering as close as possible to high-water mark. When, however, a year of exceptional flood conditions occurs, such as happened at Kansas City in 1904, or in Texas or Montana this year, the bridge goes down in the flood and its obstructive effect on the current often makes the flood conditions worse in adjacent territory.

The results of forest stripping are well illustrated by the State of Michigan. According to a bulletin just issued by the Forest Service, about 6,000,000 acres, or nearly one-sixth the area of the entire state, is now "pine-barren" land. The removal of the original growth of pine was followed by forest fires which fed by the tops and the young growth burned up a large part of the soil itself, and rendered a new growth of timber difficult or impossible. As a result, the land has become valueless and has reverted to possession of the state through unpaid taxes. Had proper methods of forestry been pursued, these lands would be producing marketable pine to-day.

CONCERNING AMERICAN RAILWAY MANAGEMENT.

A civil engineer of great ability and national reputation invented, some four or five years ago, an important improvement in railway rolling stock. We say invented, but designed is probably a better word. What this engineer did was to take a certain engineering problem and work out its solution further than any one else had carried it. He thus found the reason for certain long-standing defects in existing apparatus, and then he devised a new apparatus which overcame these defects.

Fortunately, unlike most inventors, this engineer was in comfortable financial circumstances and he was able not only to work out his invention on paper, but to construct it in steel and iron. Not only was he able to do this, but to have it introduced into actual service. He was thus able to prove that his theoretical investigations were correct and that his invention was practicable—two points over which most inventors stick hopelessly. Besides this, he hired a salesman to push the invention on the market.

Here, then, would seem to be the well laid foundations for a successful commercial enterprise: An improvement which promised to save (and we believe would save) millions of dollars a year in operating expenses to the railways of the country, the improvement demonstrated to be practicable by actual operation in regular railway service, eminent scientific backing to substantiate the claims made for the device, and finally, the nucleus at least of an organization to place it before railway officers. We may add also that the improvement was given full publicity in the technical press.

And yet, notwithstanding this excellent foundation, the superstructure was never reared. No orders for the improvement were ever secured and nothing has been heard of it for years by the engineering and railway world.

In an interview not long ago with the engineer who invented this improvement, he stated that he had expended over twenty thousand dollars in developing the invention, besides his own time, and he was willing to present it as a gift to anyone who would show competency to take it up and push it commercially.

Now why did the device fail to secure a market? The inventor's reply to this query is of especial interest. He declared that railway officers are so occupied with their regular work of administration that they have practically no time to give to the examination and adoption of new improvements, and particularly anything which it requires some effort to understand! The railway executive officer knows that every change in existing apparatus or methods means necessarily a great amount of labor in educating the entire staff to the change. Very properly, therefore, he must be convinced that a change will be absolutely beneficial before he will act—and he would like to see the man who could convince him!

To use the expressive words of the inventor: "When we tried to get my invention adopted by the railways we ran square against a stone wall." There was, he admitted, one way by which success might have been gained—that is by "grafting," the way to adoption by that certain percentage of railway officers who are susceptible to financial arguments. This engineer, however, was an engineer of high professional standards, and he preferred to lose all he had invested rather than do business in a dishonorable manner.

It has seemed to us that this true story is worth putting on record for the lessons it contains. It

illustrates again, what has often been shown, the exceeding difficulty of introducing any new invention in the railway field. The engineer who designed this was, as we have stated, a man of the widest reputation and highest standing; moreover, he has been all his life closely connected with railway work and has a wide acquaintance among high railway officials. If such a man as that, with ample means and with technical and expert ability at his elbow to aid him, cannot introduce a valuable railway invention, then how infinitesimal are the chances of the poor and unknown inventor without means!

It happened that close upon the interview with the engineer above referred to came a conversation with another engineer of equal prominence, the president of a great corporation well known for the important construction works it has carried out. In speaking of the difficulties of his company's business he alluded to its railway company clients, and declared that his firm had often the greatest trouble in securing the attention of railway officers to work which the firm was carrying out for their own companies.

Notice especially that these two men, each with opportunities for observation such as come to hardly one man in a million, speaking on totally different subjects, expressed identically the same opinion: That the high railway officer of the present day is overloaded with work and responsibilities. Overloaded to such an extent that he is obliged to neglect things to which it is his duty to give attention.

And now we are able to bring still a third witness to testify in a similar vein. This man has been all his business life in close touch with railway officers and railway operations. He now holds a position near the head of one of the largest concerns furnishing supplies to railway companies. His testimony is that the railway companies, with few exceptions, rely on his company to advise them what to buy and what to use in the particular line which he handles. In other words, these railway companies—even the largest of them—have not enough engineering ability in their management to decide for themselves what they should use and how they should use it.

And now let us turn from general statements to specific. Take, for example, the matter of locomotives. American locomotives are larger and heavier than those of any other country, but they are extraordinarily wasteful of fuel and they are probably more costly to keep in repair than foreign locomotives. This is not the fault of the locomotive designers and builders, but of the railways. It is entirely possible to build a locomotive and incorporate in its certain well tested improvements which would make it a far more efficient and economical machine. But until railway companies are prepared to give to locomotives better care on the road and in the shop, it is probably wise to put up with the present inefficient machines.

And what does better care on the road and in the shop mean? It does not mean, necessarily, higher wages for engine runners. American railways are already paying very high wages to engine runners and are entitled to receive intelligent as well as faithful service. What it means, therefore, is more supervision of these men. More care and expense in training them to use their machines properly, more energy and ingenuity on the part of executive officials to make engine runners care for their machines.

As an illustration of what better locomotives would mean in the way of economy, a paper was read before one of the railway clubs within a year, in which it was stated that a great part of the economies claimed for electric motive power could be secured without making the tremendous investment which electric operation requires, simply by adopting a few of the well established improvements in locomotive construction that have been developed during the past few years.

For another illustration take the matter of tie supply. Our railway companies assuredly expect to continue their operations for ten, twenty, fifty or a hundred years to come. They issue bonds and make leases which mature or terminate more than half a century hence. Certainly, therefore, the present day managements are in duty bound to make some reasonable provision for the future operation of their railway lines. The question is pertinent, therefore, what provisions have our railway managers made for the future supply of cross-ties? It is not too much to say that the wooden cross-tie is the foundation on which the whole railway superstructure is built. Is it not the business of the railway managers to look ahead and see what foundations will be available at least for the railways of 1930 or 1950?

It may be said that the railways have done something in the way of erecting tie preserving plants and have started tie plantations. The fact is, however, that all that has been done in this field is trifling compared with what should have been done. A dollar expended on forestry fifteen years ago would now be in condition to yield ten or twenty dollars a few years hence. Locomotive sparks, which ought to have been and might have been prevented, have set fire to vast tracts of forest and have had a large part in hastening the timber famine, which will hurt the railways as well as all the rest of the community.

We are told, however, that the growth in power and influence of the railway labor unions and of public opposition to railways, which finds expression in State and federal laws and commissions to supervise railway operations—that these things make large demands on the time of railway officers. When a general superintendent is hearing a grievance committee or answering a railway commission's summons he cannot be studying the larger problems of economic operation which are now too much neglected.

There is undoubtedly truth in this statement; but let us go back a little. With more ability in the management—closer touch with the operating force, such as was had by the master mechanic and division superintendent of thirty years ago, is it likely that the unions would have obtained quite such a dangerous power? Again, if our railway operations had been conducted with more regard to the rights of the public in the past, is it likely that public enmity to the railways would have been quite so extreme at the present day?

The past is past, of course. The serious question is whether the statements we cited at the outset of this article are true. If our railway companies are indeed so managed that important improvements are neglected and waste goes on unchecked, then indeed the situation is one of great importance, not only to the owners of the railways—those who hold stocks and bonds—but to railway shippers and travelers, railway employees, and, in fact, the whole public.

And at this point we may quote still another statement extremely pertinent in this connection. The head of one of the best known of American engineering schools, which gives special instruction in several departments of engineering work, was asked whether instruction was given in any branch of railway engineering. He replied in the negative, and when some surprise was expressed, said that he did not consider it just to the graduates to encourage them to take up a line of engineering work in which neither the salaries paid to honest and efficient men nor the chances of eventual promotion were such as should attract a man of ambition and ability. "The railways do not offer enough either in the way of present salary or future prospects," said he, "to justify us in fitting our graduates for railway work."

If this statement is a true one—and who will deny it—certainly the railways will be the greatest sufferers. The railways need men of the largest ability to conduct their affairs; but what inducements do they offer to attract young men of technical training to take up such work and make it their life profession? Is there any field of engineering work which makes such heavy demands on a man's time and energy, which loads him down with such a weight of responsibility for the safety of life and property and pays so poor a financial return as the railway service?

It is said that there are compensating opportunities offered to men of high position in the railway service and one is pointed to the many railway men who have accumulated fortunes. But the way in which many of [illegible] have been accumulated are not looked [illegible] public as they were a decade or two ago. Ad[illegible] for the sake of argument if you will, that there may be such a thing as "honest graft," by which a railway officer may make an income outside of his salary. It is surely like passing a camel through the eye of a needle to draw the line between the "honest graft" and the graft that none can defend. Besides, the man who begins with "honest graft" and pockets dollars that he did not earn finds it hard to resist the temptation to continue and to make opportunities for revenue to himself where none existed before.

Surely a business is on a wrong basis when it pays a niggardly salary to an officer of high responsibility, and tacitly approves of his use of the opportunities of his office for his own enrichment.

To no small degree, the problems which our railway managers must solve are the same as those that face the managers of our great industrial enterprises. Our promoters and bankers have bunched a dozen factories in a trust and grouped a dozen railway lines in a system; but they have little conception of the difficult problems which must be worked out to make those dozen factories or dozen railway lines into an efficient working unit. An organization can be broken up in a day, but it is the work of years to build it up and make it a smoothly operating machine. Probably the consolidation of the railways into great systems was a necessary step forward, but we have only begun to work out the problem of unifying these systems, and secure harmony of action between all departments and all divisions.

We have not written the above as an indictment of American railway officials as a class. On the contrary, we are strongly impressed with the energy and industry and faithfulness with which these men as a whole have carried heavy burdens. It is the system that is at fault and that needs a remedy. Our American railways need to make larger use of the mechanical engineer and the chemist. They need more money spent on salaries of competent executive officers in order that less money shall be spent on ineffective labor and defective materials.

LETTERS TO THE EDITOR.

Where Should Work be Stopped on a Reinforced-Concrete Beam?

Sir: In Engineering News, June 4, 1908, p. 616, a writer, initialed E. M., inquired as to where work should be stopped on a reinforced-concrete beam. Has he read the article, "The Reinforced-Concrete Reservoirs and Aqueduct of Mexico City," by James D. Schuyler, M. Am. Soc. C. E., in Engineering Record, March 28, 1908, p. 362? In constructing the roof of the reservoir, it was necessary to form the ends of the beams "a long time prior" to the ultimate completion of the beams. Tests were made at the Cindesa testing laboratory on two beams 14 days old and on two beams 28 days old. The test pieces were 19⅝ ins. deep, 7⅞ ins. wide and 14 ft. 9 ins. long; the distance between supports was 13 ft. 1 in. Square rods were used for reinforcement. The mix was 1:2:3. One beam of each age was built monolithic; the other beam had its ends formed two days before the rest of the beam. Guessing from a photograph, I should say that each end section was about 1 ft. long. The lack of weakness on the irregular line joining the old and new concrete seems to "prove conclusively that there was no weakness to be feared from this fragmentary method of molding as compared with monolithic beams, but, on the contrary," that greater strength is developed.

Yours truly,
Clinton S. Bogert.

57 E. 129th St., New York City, June 7, 1908.

Some Misleading Authorities on Grillage Beams.

Sir: How shall grillage beams for foundations be proportioned? (1) Shall they be considered uniformly supported from below the entire length of the beam, with a uniform load extending over a center portion of their upper surfaces, and the maximum bending moment at the center of the beam? Or (2) shall the beam be figured only for the load on the projecting area, the maximum bending moment being taken at the edge of the base-plate, wall, or footing above?

total load on the top = total reaction at the bottom;

a = the length of distribution of the load;

y = the width of the projecting area;

l = length of beam $= 2y + a$;

M = maximum bending moment:

Then, by Method 1: $M = \frac{W}{8}(l-a) = \frac{W\,y}{4}$

by Method 2: $M = \frac{W\,y}{2\,y+a} \times \frac{y}{2} = \frac{W\,y^2}{2\,(2\,y+a)}$

It needs but a few comparisons to show how widely different are the results obtained by these two methods of calculation.

To the writer the first method alone seems safe and correct. To his knowledge a year or so ago the foundation plans of a building were condemned by the building department of the City of New York because the grillage beams were proportioned in accordance with the second method. The owner was put to considerable expense in strengthening his grillage. Yet he supposed he had followed reliable authorities in the first place.

It is this feature which brings forth this communication in the hope that it may be interesting to some of your readers.

Johnson, Bryan and Turneaure in their "Theory and Practice of Modern Framed Structures," first edition p. 444, or eighth edition p. 482, writing of cast bases under columns say:

These bases are made strong enough to carry the entire load on their perimeters, and in such cases the maximum bending moment in the beams comes at the edge of the base-plate.

Of course, the whole question hinges upon whether cast bases are made strong enough to carry the entire load at the perimeter. *Generally they are not.* A page or two further on these same writers say:

If the base-plate is only strong enough to uniformly distribute the load over the area, the maximum bending moment in the beams is at the center.

This gives results in accordance with method 1 above.

Patton, in "A Practical Treatise on Foundations," second edition p. 346, calculates the bending moment for the projecting arm only and assumes the point of maximum bending moment at the edge of the upper course.

Freitag, in the chapter on "Foundations" in his "Architectural Engineering," second edition p. 325, takes the maximum bending moment for the upper tier of beams about the edge of the column base. The base he gives in his illustration will by no means carry the entire column load to its edges. He writes:

For the lower course of beams the calculation may be made in exactly the same manner, remembering that the point of moments is taken on the extreme edge of the upper course.

Kidder, in his "Architects' and Builders' Pocket Book," fourteenth edition p. 165, in calculating the size of beams for a wall footing writes:

The beams are computed only for the portion projecting beyond the stone footing, as the load on the beams directly under the wall produces no transverse strain.

However, this does not fully satisfy the author, as on the same page he writes:

Owing to the tendency of the beams, in bending, to concentrate the load on the outer edges of the masonry footing, and thus crush them, which action would have the same effect on the beam as lengthening the arm or projection, the author recommends that when the course above the beams is of stone, brick, or concrete, at least one-third the width of the masonry footing *be added to the actual projection.*

The Carnegie Steel Co., in their well-known handbook, edition of 1903, give four pages to I-beams used in foundations. In all cases they take the point of maximum bending moment at the edge of the base, wall, or course of beams above. This is unfortunate, for this handbook is widely used and quoted as authority.

Referring to the recent handbook "Structural Steel," of the Bethlehem Steel Co., under "Grillage Beams in Foundations," p. 244, we find the case stated correctly:

Loading is uniformly distributed over the length on which it is applied and the beam is uniformly supported from below over its entire length. Maximum bending occurs at the center of length of the beam.

The Cambria Steel Co. in their handbook "Cambria Steel," edition of 1907, p. 301; the Pencoyd Iron Works in their "Steel in Construction," edition of 1900, p. 290, and the Passaic Rolling Mill Co. in "Structural Steel and Iron," p. 209, agree precisely with the Bethlehem Steel Co.

Yours very truly,

New York City, June 4, 1908. R. F.

The Influence of Protective Coatings on the Corrosion of Iron and Steel.

Sir: Mr. R. H. Gaines' admirable and instructive paper on the corrosion of water-pipe, published in your issue of May 28, 1908, shows well some of the more important and common causes of rusting. The matter of coating is fairly and intelligently taken up, but not enough consideration is given to what may reasonably be expected from a coating and how it may be obtained. In the first place, we desire a coating which shall itself last as long as possible; if it becomes soft and earthy and lets the ground-water percolate through it, little protection is afforded to the pipe. Such, according to Mr. Gaines, is the character of the various asphalt dips; when such a coating goes to pieces the whole surface of the pipe is liable to general corrosion. The fact that it takes place mainly on the outside is evidence that constantly changing conditions assist such rusting. This will not take place uniformly because in certain soils iron does not seem to rust. As has been said, this is the case in peat because the decaying vegetable matter acts as a reducing agent, as is shown by sometimes finding beds of white ferrous carbonate under peat. Iron also does not rust in compact blue clay because the clay is so nearly water-tight that the water does not circulate in contact with the metal and electrical currents are therefore not likely to arise. Moreover the blue clay itself is lacking in oxygen, as is evidenced by its color (if it becomes oxidized it turns red).

It is not fair to class all asphalt dips alike; all pipe is not tarred with the same brush. The writer adheres to the theory that the elastic sorts of asphaltum owe their elasticity to containing a more or less oily constituent which slowly passes off by evaporation, diffusion, or solution, leaving the residue in a friable and earthy condition. In most pipe dips this is well known to be the case, as the oily part, which may be "dead" oil of tar or it may be oily petroleum residue, is added in the dipping tank from time to time as required. The more permanent this oil ingredient is, the more lasting will be the coating.

The varnish enamel which was applied to about half of the Rochester pipe is mildly criticized because it did not afford absolute protection. No coating will ever do this. These pipe sections were 28 ft. long, weighed from 2 to 2¼ tons each, were hauled on wagons many miles over country roads and across fields, were dumped by the side of the ditch, lowered into place by the ordinary methods, field-riveted by gangs of tramp riveters, and after a time were covered. More than ordinary care was undoubtedly taken in doing all this, but it is utterly impossible, and always will be, to handle such pipe and not abrade the coating in occasional spots. It makes no difference what the coating is, this is true of all. It is a necessary condition of the pipe-coating problem. These spots ought to be touched up with paint; but the paint is not as durable as the coating (that is why the coating is used); it is very difficult to find all the spots when the pipe is in the ditch, and when gravel and stones are shoveled in on top of the pipe, in covering it, some new bare spots are likely to be formed. Some of these bare spots will happen to be where rusting will not take place anyway, but some will be in unfavorable places, and in time there will be a hole at such a place. If the coating itself is closely adherent and durable, the hole will be no larger than the original little bare spot, but if it is a poor coating the corrosion will spread over the neighboring surface.

The little, sharply defined hole may be plugged or patched but this is much more difficult with broadly distributed corrosion. It is not likely and it is not reasonable to expect that we will ever have a coating which will enable us to handle two to five-ton sections of pipe in the ordinary way and never have a rust leak. If these rust leaks are relatively few and are not like great breaks, such as occur so often in cast pipe, and may be taken care of by reasonable maintenance, then the water main is as safe as we ought to expect. That is what this enamel coating seems to have done. The leaks are little sharply-defined holes, not greatly affecting the capacity of the pipe. The coating is not to blame for these holes; if the coating had been there, there would have been no holes.

What is needed in this problem is constructive, not destructive, criticism. Here are 13 or 14 miles of enameled 38-in. pipe which has been built 15 years and in that time about two small leaks per mile have been produced, amounting to the destruction of perhaps a couple of square inches of ¼-in. plate per 25,000 sq. ft. If the corrosion were general it would be another thing, but these small sharply defined holes do not weaken the plate in a way to cause danger of bursting. We should not only investigate the causes of these perforations, that is indeed important, but we must also be interested to know why the rest of the plate remains uninjured. The fact that there are about five times as many perforations per mile in the asphalt-coated pipe as in the enameled, is of no small importance.

It should be remembered also that this was the first large enameled work ever attempted and, while it was carefully and faithfully done, important improvements have since been made in the application of the enamel. The New York Navy Yard had an enameling plant similar to the one used at Rochester but, after some years' study of its operation, this was torn down and a new and essentially different plant was built so that with the new and more scientifically constructed outfit the output of pipe, which was fairly good before, has been greatly improved. In considering new work the possibilities of all this improvement should be taken into account.

A. H. Sabin,
Assoc. M. Am. Soc. C. E.

432 Sanford Ave., Flushing, N. Y., June 8, 1908.

Notes and Queries.

An error in our article on the settlement of the Homeopathic Hospital at Pittsburg, p. 2 of our issue of June 11, made the designed foundation pressure appear to be 8 tons per sq. ft. This of course should have read 4 tons per sq. ft., a figure more suitable to footings on natural clay soil.

By another error we misspelled the name of the engineer active in the work of blocking and jacking up the settling structure. Mr. Herman Laub, M. Am. Soc. C. E., of Pittsburg, was the man in charge of this work.

Our attention has been called to errors in the article in our issue of June 11, "A Device to Increase the Effective Head of a Water-power Plant by Utilizing Waste Water." Through a typographical error one equation was made to read:

$$\text{Work gained} = Q.\ (h + h_1) - Q.\ \frac{\sqrt{h\ h_1}}{\sqrt{h + h_1}}$$

It is seen from the work preceding and following this equation that the proper form should be:

$$\text{Work gained} = Q.\ (h + h_1) - Q.\ \frac{h\ \sqrt{h_1}}{\sqrt{h + h_1}}$$

With this article are shown two curves described as "showing the relation between water ratio and efficiency in one instance and between water ratio and efficiency in the other." From the curves themselves it is at once seen that this phrase should be: "Showing the relation between water ratio and efficiency in one instance and between water ratio and head ratio in the other." The captions on Figs. 1 and 2 were accidently transposed and should read as follows:

"Fig. 1. Experimental Arrangement of Herschel's Fall Increaser at the Holyoke Testing Flume, Holyoke, Mass."

"Fig. 2. Clemens Herschel's Fall Increaser as Applied to a Hydro-Electric Power Station."

The nature of these errors is so apparent that the correct forms must have been immediately recognized in each case.

STEEL RAILS FOR PRESENT SERVICE; THEIR MANUFACTURE AND THEIR FAILURES.

At a meeting of the Western Society of Engineers on May 18, Mr. P. H. Dudley* presented a paper on "Steel Rails for Present Service; their Manufacture and their Failures." He opened with the statement that 25 years ago he submitted to the New York Central Ry. the design for the first 5-in. 80-lb. rail in the United States. During the previous four years he had, with his dynagraph or track-inspection car, taken diagrams of the surface conditions of thousands of miles of track laid with rails ranging from 52 lbs. to 67 lbs. per yd. in weight and from 3½ ins. to 4½ ins. in height. The rails were of various makes, each of which developed certain individual peculiarities in the finish. The diagrams drawn by the apparatus had a longitudinal scale of 1-in. to 50 ft., while the vertical scale (for irregularities of surface) was full size.

Railway officials were at first of the opinion that bad sections of track detected by this mechanical inspection could be brought into proper condition by more ballast, ties and labor. Inspections of track improved in this way, however, frequently showed the same conditions of rail surface, although the general character of the track had been improved. It was shown conclusively that while much could be done by general improvements in regard to materials and maintenance work, there were limitations imposed by the fact that a considerable proportion of the irregularities were inherent to the rails themselves and not to the track as a whole. Indeed, in some cases new rails were shown to have minute waves in the surface of the head. When these were replaced with other rails having a smoother finish, there was a decided improvement in the track condition and in the riding of the cars.

The early steel rails lasted as long as six to ten of the iron rails they replaced. The depth for the splice bars was low and inadequite, however, and the joint fastenings were inefficient. In a short time, therefore, the rails acquired per-

*Consulting Engineer, 80 Pine St., New York, N. Y.

manent set of varying character, which was classed as follows: 1, Joints low and centers high; 2, Joints and centers low and quarters high; 3, A series of short waves. There were often combinations of Nos. 1 and 2, and Nos. 2 and 3. The wheel loads were practically the same as on the older iron rails, but the static loads were augmented by the wheel effects or dynamic shocks incident to the low joints and irregular surface, and this resulted in high train resistance. The track construction below the rails was of ample strength for the service, provided that the moving wheel loads could be distributed over a greater length and area of the roadbed. This could be effected by the use of stiffer rails, which would distribute the load over the wheelbase and thus relieve the individual ties from the severe loads sustained under the more flexible rails. Difficulty was experienced, however, in convincing railway officers that the increased cost of rails of the new section would be warranted by the practical results obtained.

The New York Central Ry. accepted the position that it would be economical to use a 5-in. 80-lb. rail which with only 23% more metal would be 66% stiffer and 40% stronger than the 65-lb. rail then in use. The new rails were first rolled in April, 1884, and laid in the track in July of that year. Mr. J. D. Hawks, then Chief Engineer of the Michigan Central Ry., designed a rail of the same weight and height, which was laid in 1886. President Roberts, of the Pennsylvania Ry., also ordered a 5-in. 80-lb. rail designed after he had ridden over the new rails of the New York Central Ry. The supervisors had great trouble with the old Pennsylvania 4½-in. round topped rail, which rolled out outward so as to spread the gage. They were of opinion that this action would be greater with a 5-in. rail. It was explained, however, that the new rail was designed with a comparatively flat top (12 ins. radius) so that the wheels would tend to hold the rails vertical. This was found to be the case in service. In 1892, the New York Central Ry. ran the first 100-ton locomotive on the first 100-lb. rails in the United States.

We give below an abstract of part of Mr. Dudley's paper:

The necessity was recognized for increasing the physical properties of the metal to correspond with the mechanical properties, and from 1890 to 1900 I had made over 600,000 tons of rails with 0.60% or more of carbon (according to the section), the phosphorus being limited to 0.06% or less. These included 95-lb. rails for the Boston & Albany Ry. and 75-lb. rails for the Mohawk & Malone Ry. They were rolled by the Bethlehem Steel Co., while Mr. John Fritz was superintendent, as he was the only manufacturer who admitted at that time that such rails could be made. Both railways paid a premium for this high grade of steel.

The heats after being recarburized in the converter were poured and remained in the ladle from 5 to 6 minutes, to allow the chemical reactions and oxidation-products to escape before teeming the ingots. The ingots were stripped, thrown down in the pits, and charged into horizontal furnaces for equalizing the heat before blooming. The 26-in., three-high blooming-train of 11 passes was used. The blooms were cropped until sound steel was obtained, then chipped under the steam-hammer, and again charged into horizontal furnaces for reheating and then rolled in 11 passes into rails. They were finished at between 950° and 1,000° C., as nearly as could be measured by the Siemens copper ball and water pyrometer. The Bethlehem rails on the Boston & Albany Ry., after 16 and 17 years' service on heavy grades and sharp curvatures, have lost only about ⅛-in. in height for the large volume of traffic which has passed over them.

It was shown that sound ingots could be made in which piping was the least of their defects. The chemical composition should serve two important functions: 1. To provide the basis for the physical properties desired in the steel; 2. To secure sound ingots. This requires the adjustable feature of the composition which was used in making the high-carbon low-phosphorus rails. When the phosphorus limit must be raised to 0.10% owing to the character of the ore, the carbon for 100-lb. rails to be used where the temperature reaches 20° or 30° below zero should not exceed 0.45% or 0.50%. The silicon can be from 0.10% to 0.15% and the manganese about 1%. For ingots with length about 2½ times the base width, sound ingots can then be made by holding the steel 2½ to 3 mins. after recarburizing in the converter, or about the same time in an intermediate ladle before pouring. The nozzle of the ladle should not exceed 1½ or 2 ins. diameter, to ensure a solid stream of metal and to prevent carrying air into the mold.

In order to study the defects in ingot structure besides those due to pipes, I commenced lettering the rails from the ingots for the New York Central Ry. and Boston & Albany Ry. in December, 1892, at the Lackawanna Iron & Steel Co.'s plant, Scranton, Pa. The rails were 0.06% in phosphorus. The carbon was 0.55 to 0.60% for 80-lb. rails and 0.60 to 0.70% for 95 and 100-lb. rails. These rails after 12 to 16 years' service have developed comparatively few base fractures, which were nearly equally divided between each of the letters. Out of over 500,000 tons, only 20 rails piped in the webs and heads have been found to date, though there is about 0.25% of split heads, which are common to all of the letters.

There is a slightly greater percentage of defective rails in the letter A (from the top of the ingot) than in either B or C. Those rails were all made from ingots which were cast in the pits, and as soon as they were stripped were thrown into a horizontal position, loaded upon the ingot trucks and charged into horizontal heating furnaces. The chemical composition was adjusted to make a sound ingot. A great many of the ingots (as stickers) were broken under the drop hammer to see the solidity of the metal, and it was rare to find a central cavity of ⅛-in. diameter in any of the ingots after they were cold. The rails are giving exceedingly slow rates of wear, and only near the inside running edge of the upper corner of the head of the A rail for about one-third of its length do they show slight inclusions of gas or slag in the structure of the upper part of the ingot.

The B and C rails rarely show any defects. The letters upon those rails can be found on most of those now in the track. The New York Central Ry. has been restencilling a number of those rails with white paint, indicating the letter so that persons can examine the rails and see the different rates of wear between the A, B and C rails. The A rail usually wears slightly faster than the B or C rail. Rails which have been in service 16 to 17 years and have carried from 200,000,000 to 250,000,000 tons of traffic have lost only from 1/16 to ⅛-in. in height in the center of the head. The rails on the curves show but little flange wear. The effort in making those rails was to secure a slow rate of wear by chemical composition and not by cold-rolling. Few half-moon breaks in the base have occurred in those rails after their long service.

It is not generally understood that steel for rails can be rolled too cold during their manufacture. It is found by experience that cold rolled rails, which have been manufactured extensively since 1900, break to a greater extent in the tracks where the temperature falls to zero or below than the rails which were rolled at the ordinary working temperature. The cold rolling is beneficial for the rate of wear in the head, but when the rails are rolled to near or below the critical temperature for the steel, it is detrimental to the section as a girder. The base, web and head will be chilled and hardened so that the ductility is decreased for the ordinary chemical composition of the section, and the rails are injured under the straightening presses.

The half-moon breaks which have occurred in the rails manufactured in the past four or five years are generally associated with cracks or seams in the base of the rail.

Many consider that these are the primary cause of the fractures. The more recent physical examinations of broken rails show that associated with these seams the metal is usually brittle, having been chilled in rolling. The flange checks easily under a light blow of the sledge. The fractures can in many cases be traced directly to the initial strains in the metal, due to gagging to straighten the rail at the time of manufacture. The base of the rail on one side will check from the bottom upwards and in an inch or two from that the top of the flange will check from the top downward. They are detailed progressive fractures even though completed under a locomotive or train. Usually when found some part of the fracture has previously oxidized or discolored, showing that it has been days, weeks and sometimes months in developing.

The gagging was sufficiently severe to put reversed bends in the edge of the base and has left decided initial stresses at the junction of the base and web and in the flanges of the rails due to permanent sets of the metal in gagging. The majority of the moon or crescent shaped fractures are on the top of the ties, the final being through the web and as a vertical shear with slight curvature through the web. Comparing these fractures with those from the supports of the drop testing machine, they are found to be identical except as to length of curve when the rail shears over the support. Increasing the thickness of the base for colder rolling than has been considered permissible does not check the tendency of the metal to fracture in the edges of the base under the reversed strains of the gagging process. The cold rolling reduces the ductility the same as though greater additions were made of carbon or phosphorus.

The fractures in the base of the cold-rolled rails are not confined to the A rails, representing the top of the ingot, as is generally understood. They are distributed through all the rails from the ingot, and in a few cases have been identified as confined to a single ingot of the heat. Out of 201 specimens of broken rails, 43 were A rails, 46 B, 33 C and 18 D rails. The D rails form the smallest percentage of any of the letters in the track, for the reason that in long ingots they generally make the most seconds and are rejected as first-class rails. There were 61 rails out of 201 specimens in which the letter had become so oxidized as to prevent identification. The A rails formed about 21% of the letters identified, the B rails 22%, the C rails 18%, and the D rails about 9%. The D rails are from the bottom of ingots making four rails.

The few failures I have described are those of my observation under high speed trains where the temperatures were 20 to 30° below zero for several days at a time. In the winter of 1906 and 1907, which had the longest protracted waves of low temperatures in many localities the Weather Bureau has yet recorded, I saw but one or two direct tension breaks of rails. All other fractures were developments of injuries, strains or defects in manufacture.

The numerous split heads of rails of recent years, called piped rails by the trackmen, are really due to heat failures. In long ingots the steel of the upper part is not deoxidized as much as the average, there being a well-defined exterior envelope not securely united to the spongy central core. The wheel loads cause the metal in the bearing surface of the rail to spread laterally and become loosened from the core, and the widening layer of metal eventually splits the metal of the core. The surfaces of the vertical splits become discolored in a short time, and they are often reported as flaws or pipes. About ⅛-in. to ¼-in. under the bearing surface of the rail there are often minute layers of slag (silicates of manganese) from the chemical reactions of the recarburiser. These permit the upper part to spread easily and split the metal beneath. The split may develop at the end of the rail, but more often occurs in one or two places at the centers or quarters. The pouring of the ingots too quickly after the recarburising of the steel seems to be a great factor in the cause of split heads.

Various forms of defects would be classed as "pipes," by the track men who report rail fractures, but each might require a different method for its correction. The railway company should not simply tell the manufacturer when rails fail. It should investigate and tell him the reason why they fail to meet the conditions of service. In the development of rail transportation, the users of rails have been obliged to increase the wheel loads and tractive efforts of the locomotives and the speeds of the trains, in order to meet traffic conditions. The rail makers, at the same time, in order to meet the demands, have shortened the time necessary for some of the processes of manufacture. It is necessary that the rail makers and users should get together, and it is gratifying to find that they are now arriving at the same facts and conclusions, from which material benefits will result. In conclusion, I quote the following remarks made by Dr. C. B. Dudley, of the Pennsylvania Ry., in commenting upon my own specifications for rails.

My old teacher in metallurgy used to say that the making of steel is a chemical operation, and that chemical operations require time as an essential element. My own thought on the subject of rails has been that we have just started to get hold of this problem. I want to call attention to the requirement in the specifications which Dr. P. H. Dudley referred to, that the metal should be held 2½ minutes after the final additions are made in the converter. I have been fighting the manufacturers of rails for over 20 years, and I have been trying for years to get them to hold the metal in the converter or the ladle for a little while, so as to give time to enable the necessary chemical reactions to take place. I am delighted to know that one specification has brought that thing about.

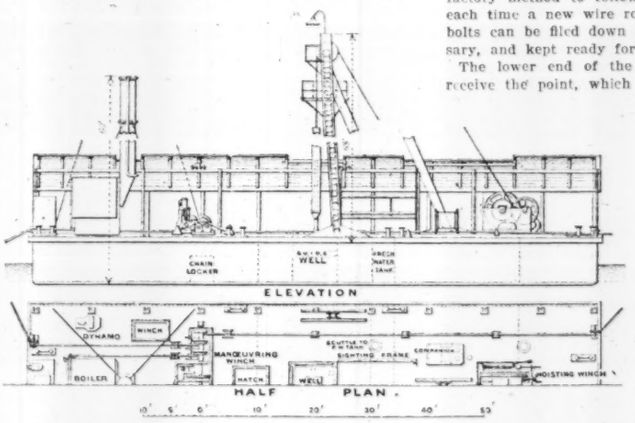
THE WORK OF THE LOBNITZ ROCK BREAKER IN SUBAQUEOUS ROCK REMOVAL.

Over twenty years ago Messrs. Lobnitz and Co., of Renfrew, Scotland, began manufacturing the Lobnitz Rock Breaker for use in breaking up subaqueous rock pric. to dredging, and since that time the machines have been used in various kinds of work in many places all over the world, including the Manchester, Eng., Canal, the Suez Canal, the river improvement work on the Danube and more lately in the harbor work in Buffalo, N. Y. Finally, the Isthmian Canal Commission has recently given an order for one of the machines to be delivered for work on the Panama Canal on Aug. 1 next. However, in all this time there have been very few available data concerning the performance of the device, either in connection with the amount of work turned out or the cost of excavation, so that comparison between the Lobnitz method of rock

removal and the generally used blasting has been reserved for the few who have had experience with both methods, and who, for reasons best known to themselves, have kept secret such data as they have accumulated.

In the Proceedings of the Institution of Civil Engineers, vol. 170, part 4, Mr. George D. McGlashan, Assoc. M. Inst. C. E., who is connected with the harbor work at Blyth, England, gives, in a paper entitled "Removal of Subaqueous Rock at Blyth," an extended account of the procedure and costs of the operation of a Lobnitz Rock Breaker, which has been at work for some time in that harbor. Although the costs of labor and supplies are much lower in England than in this country, this first* authoritative account of an extensive work with the Lobnitz machine, as recently developed, is of sufficient interest to warrant the almost complete transcript which we reproduce below.

The following paper has reference to a recent development of a method of removing subaqueous rock, adopted for the work now in progress at Blyth Harbor, Northumberland. In 1906 the Blyth Harbor Commissioners decided to carry out an extensive scheme of improvement, and among the works embraced in the scheme was



THE LOBNITZ ROCK BREAKER, USED FOR SUBAQUEOUS WORK IN BLYTH HARBOR, ENGLAND.

the deepening of the harbor to 24 ft. at low water of spring tides, involving the removal of about 500,000 cu. yds. of rock. For this purpose it was decided to employ a Lobnitz Patent Rock Breaker, and so successful were the results that a second machine was obtained this year (1907).

This method of rock breaking consists in the repeated blows of a long, heavy pointed chisel or ram, which falls by its own weight upon the rock to be broken. No explosives are required. The machine consists of a barge upon which stand the tripod legs supporting the ram, a winch for hoisting the ram by means of a wire rope led over a sheave at the top of the tripod, another winch for operating the chains that maneuver the barge, an ordinary marine boiler for supplying steam to the winches, and smaller supplementary machinery and plant.

DESCRIPTION.

The barges of the rock breakers at Blyth are of steel and measure 100 × 28 × 8 ft.; and they are divided into five water-tight compartments, one of which serves as a fresh-water tank for the boiler-supply, and the others are utilized for cabin accommodation for the crew and for the storage of reserve wire ropes, chains, etc. At the center of No. 1 barge there is a well through which the ram works. This machine cannot work nearer to any quay-face than one-half the beam, or 14 ft. In the second rock breaker the ram works at one end of the barge, so that the rock can be broken close up to quay-faces; this barge, however, has the disadvantage of considerable movement in the water while the machine is at work. The guide for the ram is fitted with powerful volute springs to lessen the lateral shock of the blows; the tension of these springs is adjusted by wedges. The boiler and machinery are on deck. The legs of the tripod are of a box section, are built of steel and are riveted to the deck; they are sufficiently high to allow of the point of the ram being raised level with the deck for examination or renewal of the point.

The rams are 40 ft. and 50 ft. long; they are made of forged steel, turned and machined all over, and tapered to conform to the total stresses at each section; the maximum diameters are 19½ ins. and 16¾ ins. respectively, and the weight of each ram is 15 tons. The shorter the ram the larger its diameter must be for any given weight, and, consequently, the better it is able to withstand the stresses due to the blows; to determine the length (in tidal waters) the required depth of water at low water is added to the rise of average spring tides, and the ram should be about 5 ft. longer than the sum. At Blyth the average rise of spring tides is 14 ft. 6 ins. When not in use, the ram is hoisted out of the water and slung with chains to the tripod.

The wire rope attachment at the upper end of the ram consists of a couple of corrugated gluts 12 ins. long, embracing the rope and let into a recess bored out of the head of the ram. Six tightly screwed set-bolts, 1¾ in. diameter, passing through the ram head, cause the gluts to grip the rope. During the eight months that No. 1 rock breaker has been at work, this attachment has failed only once, and that failure was caused by an inexperienced man. Great care should, however, be taken that the set-bolts are thoroughly tightened up, because, in certain circumstances, the consequence might be serious should the rope slip out. It is important to have a spare set of these bolts, for after being used several times, a "burr" or "rag" forms upon their ends when screwed up against the gluts, and it is then difficult to unscrew them, and in one or two cases they had to be drilled out. A satisfactory method to follow is to use the spare set-bolts each time a new wire rope is put on; the original set-bolts can be filed down at the ends, retapped if necessary, and kept ready for use.

The lower end of the ram has a tapered socket to receive the point, which resembles in shape an armor-piercing projectile. This point is of vital importance, and it is made of specially hardened steel, the composition of which varies according to the kind of rock to be broken. The hardness of the steel increases towards the center, which has the effect of preserving the pointed shape as the point wears—a very important feature in effective breaking up of the rock. The life of one of these points is about 1,000 working hours. The point is secured to the ram by three set-screws, which are set into an annular recess in the spigot of the point; the heads of the set-screws are sunk flush with the face of the ram. Considerable difficulty was experienced in withdrawing the point from the socket in the ram, and improvement is required in this direction. On one occasion, hydraulic pressure, amounting to about 5 tons, was applied at the top of the spigot, and at the same time steel wedges were driven in between the point and the ram, yet it required a whole day to produce any movement of the point. The wedges tended to damage the bearing area of the ram upon the spigot. The hydraulic pressure was applied through a small hole leading into a recess bored out of the ram at the head of the socket. Heating the foot of the ram is sometimes effective in loosening the point, but this method is not altogether advisable. Surrounding the foot of the ram and let into it, is a hoop of specially hard steel, which strengthens that part of the ram against the bursting effect of the spigot, and, in addition, serves to resist the wear, and so protects the extreme end of the ram. With continuous working, the point, and 2 or 3 ft. of the ram, become highly polished. For about 12 ins. above the hoop the ram was found to have been hollowed out, after eight months' working, 3/16 in. by the abrasion of the rock.

The hoisting winch is driven by a double-cylinder non-condensing engine, supplied with steam at about 100 lbs. pressure from an ordinary marine return-tube boiler, and suitably geared to a shaft upon which rides loosely a barrel 3 ft. in diameter; the surface is spirally grooved to prevent the coils of wire rope riding upon each other. A chilled steel center, embraced by a steel spiral coil-clutch attached to the barrel, is keyed to the shaft. The coil-clutch is actuated by a system of levers, and is provided with a small spring to assist it in releasing its hold when put out of action. This spring can be adjusted to prevent any "seizing" of the coil. The coil-clutch suddenly snapped one Monday morning, immediately after the tightening force had been applied, possibly owing to a keen frost that had set in the night before. Since then, if the winch had been standing for any length of time during frosty weather, duck lamps were placed in the vicinity of the coil to warm it, before putting the winch into operation. The winch is provided with an ordinary brake. The exhaust steam is carried through a feed-water heater, and thence alongside the funnel. A feed-pump worked by the winch supplies the boiler through the feed-water heater. The maneuvering winch is driven by a double-cylinder engine, and has six independent reversible chain barrels, fitted with warping ends; it works all the necessary mooring chains, and is operated by one man. For night-work, the rock breaker is fitted with forty incandescent 16-c. p. lamps in clusters, supplied with current from an engine and dynamo on the barge.

METHOD OF OPERATING.

To operate the rock breaker, the barge is first brought over the site, the surface of the rock having previously been dredged clean, and there it is securely moored in position by single fore and aft cables and side chains at each quarter—six chains in all. The ram is then gently lowered until the point rests upon the rock, and a gage, painted on the ram, indicates to the hoisting winchman the required height of lift, generally about eight feet. When lifted, steam is partially shut off to prevent the winch engines racing, and the coil-clutch is released to drop the ram. The operation of raising and releasing the ram is continued until the rock is penetrated to the required depth. The barge is then moved to a spot three or four feet away, and the ram allowed to penetrate the rock to the same depth as before, after which it is moved another three or four feet, and so on.

Each new position of the ram must be fixed with great care, and this is effected by two sighting poles on shore being kept in line with two sighting rods on board. The space between adjacent spots penetrated by the ram in one direction is called the "pitch," while the spacing in a direction at right angles is called the "advance." The pitch and advance are always made equal. The pitch first adopted at Blyth was 3 ft., but was increased to 3 ft. 6 ins., then to 4 ft., and ultimately to 4 ft. 6 ins. This latter pitch is now maintained throughout. The rock removed consisted, for the greater part, of the calcareous sandstone commonly found in the coal measures, portions of which were almost as hard as granite. The beds of sandstone alternated with thin layers of shale and sometimes of coal. The dredging results of the various pitches were carefully watched, but the only perceptible difference between the 3-ft.-pitch and the 4-ft. 6-in.-pitch was that with the latter the pieces of broken rock were larger than with the former, but there was no practical difference in the rate of dredging. Theoretically, there ought to be an economical pitch and advance, according to the degree of hardness of the rock to be broken, and it is worth while ascertaining this pitch by experiment, if the character of rock is fairly uniform over large area, but where the rock is varied in character, it is advantageous, for practical reasons, to ascertain the best average pitch and advance and maintain them throughout. The total penetration is generally 3 ft.; with a greater penetration there is the risk of the ram occasionally sticking fast in the rock. The ram is generally made to fall 8 ft., and with this fall about four blows per minute can be delivered. The number of blows for a penetration of 3 ft. varied from five to fifteen, according to the hardness of the rock, but for fairly hard sandstone eight blows may be taken as an average. The pieces of rock broken with a 4-ft. 6-in.-pitch average about one-fourth of a cubic foot, but occasionally there were pieces weighing about a ton. The rock is generally so well broken up that it can be dredged fully 15% faster than blasted rock, and a uniform surface on the rock is obtained.

Experiments were made with the rock breaker on hard rock exposed at low water, and showed that the rock was completely pulverized on the spots where the ram fell, and, for about a foot around each hole made by the ram, the rock was broken into small pieces and forced up above the original surface; beyond this the rock was thoroughly fissured, and some of the pieces were forced up. The thorough breaking up of the rock is an advantage for dredging purposes, as compared with blasted rock. It frequently happens in blasting rock under water, when the strata is horizontal, that the rock surrounding the lower portion of the bore-hole containing the shot is completely shattered, but the upper panels are only fissured, and not dislodged due probably, in part, to the overlying weight of water. The dredger has, consequently, considerable difficulty in "breaking into" this rock when commencing to dredge a new area; this difficulty does not occur when the rock breaker is used.

The rock breaker was originally fitted with two sighting-frames, each having a vertical sliding bar, and allowing of a total advance of the barge of 13 ft. 6 ins. for each position of the poles on shore, but this advance was found to be insufficient owing to obstructions between the barge and the shore, and also to allow of spanning graving-dock entrances, etc. A sighting-frame was therefore erected along each side of the barge for nearly its full length, allowing of a total advance of about 80 ft. before the poles on shore need be moved. At night time the poles on shore are indicated by lamps. The poles are placed alongside pegs previously put in position and are at right angles to a base line, which is plotted upon a plan kept in the office, and upon which the progress of the rock breaker is recorded day

*Descriptions of the Lobnitz Rock Breaker have appeared in Engineering News as follows: Jan. 26, 1889, p. 69; Dec. 20, 1894, p. 507; May 3, 1906, p. 499; Aug. 2, 1906, p. 125; Feb. 28, 1907, p. 236; Apr. 2, 1907, p. 383.

by day. A graduated measuring-wire, wound around a small drum on board, with one end fixed to the base line, gives the position of the barge. Some difficulty was experienced in preserving the correct positions of the barge when ships lay between it and the sighting-poles; this difficulty was, in some measure, overcome by maintaining the bearing of the base line on a mariner's compass, and by careful manipulation of the maneuvering chains.

The wire rope used at Blyth for lifting the ram is 5 ins. in circumference and 167 ft. long, and is composed of six strands surrounding a hemp core. An eye is spliced at one end for attaching to the drum. This wire rope is subject to severe usage, and consequently its life is short, so that it is one of the chief items of maintenance. Should the winchman apply the friction clutch before the ram has struck the rock the wire rope is subject to a severe pull, and a severe stress is put upon the winch itself; should he, however, be late in applying the clutch the wire rope will spin off the drum and kink at the head of the ram, and also close to the drum. With practice men acquire considerable skill in operating the winch, but, even when the application of the clutch is correctly timed, a certain amount of slackening of the rope invariably occurs, which sometimes forms a kink at the head of the ram. There are two places where the wire rope tends to fail, one near to the ram head where the kink occurs and the other at the drum, due to friction. Considerable friction, and consequent wear of the rope, also takes place at the sheave, which is 3 ft. in diameter, for at the moment the ram has struck the rock the rope is at a standstill, but the sheave continues to revolve by virtue of its kinetic energy; at Blyth, however, none of the wire ropes have had to be taken off on this account. To lessen the sharpness of the kink at the ram head the wire rope is laid with serving wire for a distance of 15 ft. from the ram-head attachment, and a later improvement is to worm the rope with ¼-in. soft iron wire before putting on the serving. There is great difficulty in getting wire rope of suitable quality, as it must be soft enough not to be affected by kinking, hard enough to resist friction, and with a sufficient margin of safety for working. Experiments are at present being made at Blyth with various kinds of wire rope from different makers, but up to the present the longest life of a wire rope has been 495 actual working hours. At least two spare wire ropes are always kept on board ready for use.

In a harbor or waterway the shore fastenings for the mooring chains of the barge are an important matter, and if ordinary single or double fluked anchors are laid down in a harbor bottom they may be a source of danger to shipping. Based on the experience at Blyth the author's opinion is, that the best system of land mooring for rock breakers, where quays are concerned and where a large amount of rock has to be removed, is to have chains attached permanently by a diver to the quay-face, as low down as possible, and of sufficient length to be brought up to near the top of the quay, where the ends are temporarily fastened. The chains are spaced at convenient intervals along the quay, and are easily brought into use by shackling them to the ends of the rock breaker's chains. This affords a more expeditious and convenient system of mooring than that of a bridle chain along the quay. The initial cost of laying these chains will be more than compensated for by the saving in labor, and by the time that the rock breaker itself would probably otherwise be idle. These moorings can, moreover, be used by the dredgers.

The rock breakers at Blyth work on double shift, and are manned by two crews, each consisting of four men: the skipper, the hoisting winchman, the maneuvering winchman and the stoker. It has been found that seafaring men make the best skippers, but they must be active, intelligent, and with a fair education. It is an advantage if the hoisting winchman is somewhat of a mechanic, as he can then more readily understand the cause of, and possibly remedy, any trifling breakdown of the machinery. Each crew works a week on day-shift and a week on night-shift alternately, making 11 shifts of 12 hours each per fortnight per man.

COST DATA.

Mr. McGlashan then proceeds to give some cost data of the operation of the breaker in this particular work. The reader is again reminded that in examining these data it should be remembered that the unit prices for labor and material are almost invariably lower than those that obtain in this country. However, these unit prices are given and a comparative estimate for American practice may be made.

The following are the full time weekly wages paid to crew:

Skipper	$10.70
Hoisting winchman	9.70
Maneuvering	8.30
Stoker	8.30
	$37.00

The coal-consumption averages 2.7 tons (of 2,000 lbs.) per 24 working hours. A large wooden tank carried on a barge is used to convey fresh water to the rock breakers. The level of the bottom of this tank being above the top of the tank in the rock breaker, no pumping is required. The consumption of water is about 17,000 gals. for a full working week. Salt water could be used, but for many reasons it is less economical.

Weather is a factor much affecting the cost, and in this connection the author has observed that the motion of the rock breaker due to 18-in. waves causes the ram in falling to strike the guide, thereby lessening the force of the blow, and necessitating a larger number of blows for a given penetration.

When rock has to be removed above low-water level in tidal harbors, the time during which the rock breaker can work is limited by the height of the rock and by the range of the tide, and it is an advantage if there is rock to be broken in deeper water close by. It is safer only to work on high rock with a rising tide, for then should the wire rope suddenly fail, or come out of its attachment, the flotation of the barge may be used to lift the ram, and when the latter is clear of the ground, the barge can be hauled into a safe position. Serious damage might ensue to the barge if the wire rope failed when working on high ground on an ebb tide.

A systematic method of recording the results of the rock-breaking is essential for economical working, and the author therefore adopted a system of "Daily Recording Sheets," compiled from the returns, from which the quantity of rock broken per day is obtained. These sheets give the following information: the number of the "ordinate" (an ordinate is a line followed by the rock breaker at right angles to the base line), the pitch, the advance from the last ordinate, the distance of the ram from the base line, the penetration of the rock for each series of blows, the number of blows for each position of the ram, etc. All delays and stoppages, with the reasons, were also recorded, together with the times of stopping and re-starting work. In this way, the progress of the work could be closely followed, and any laxity in the working of the rock breaker immediately detected, as well as the stoppages arising from preventable causes.

It was ascertained at Blyth, by soundings taken both before the rock was broken, and after the dredging, that when the ram penetrated 3 ft. the rock could be dredged for a depth of 2 ft. 6 ins.

As rock breaker No. 2 was only put into operation recently, the following particulars refer to rock breaker No. 1.

The maximum quantity of rock broken in one week was 1,975 cu. yds. The total quantity broken over a period of 27 weeks, including holidays and other stoppages, was 24,535 cu. yds., giving 908 cu. yds. as the weekly average.

During the period of 27 weeks 229 shifts were worked, each of 12 hours, and since eleven shifts constitute a full week, $\frac{24,535}{229} \times 11 = 1,177$ cu. yds., is the average for a full working week.

The following is an analysis of the rock-breaker's working time over the 27 weeks above referred to, derived from the daily record sheets:—

Delays (excluding holidays) due to—	%
Shifting moorings to new positions, and picking up and shackling together mooring chains broken by ships	9.12
Traffic	3.18
Repairs, including changing of wire ropes and ram points	20.68
Weather and moving to new moorings and berthage at week ends	5.75
Boiler cleaning, etc.	6.54
Tide	1.28
Meals	4.75
Total delays	54.30
Actual time breaking rock	45.70
Total working time	100.00

The total cost of breaking the rock is obtained as follows:

Details of working costs for 27 weeks—		
Wages of crew, towage, supervision and proportion of expense of water, and coal conveyance	$2,112.48	
Coal (net cost)	673.42	
Water* (net cost)	99.64	
Stores	84.87	
		$2,970.41
Maintenance—		
Repairs, labor and material	$360.30	
Boiler cleaning	48.67	
Five wire ropes	358.61	
Clutch coil and small springs	214.13	
Sliding disk	52.92	
Two ram points	155.73	
		$1,190.36
Total expenditure over a period of 27 weeks		$4,160.77

*Net cost of water = 26 cts. per 1,000 gallons. The cost of transport and delivery of water, namely, 44 cts. per 1,000 gallons, is included in the item of $2,112.48.

Since the total quantity of rock broken in the 27 weeks was 24,535 cu. yds., the working cost per cubic yard is—

$$\frac{\$4,160.77}{24,535} = \$0.1696$$

The cost of the rock-breaker (including ram) was $33,092.20, whence—

Interest on capital	at 4 %	$1,323.70
Depreciation	at 2½ %	827.30
Insurance	at 2 %	661.80
Total		$2,812.80

or $1,460 for 27 weeks.

So that the amount per cubic yard is—

$$\frac{\$1,460}{24,535} = \$0.0595$$

Total cost of breaking rock (including interest, etc.) = $0.1696 + $0.0595 = $0.2291 per cu. yd.

The 2½% allowance for depreciation is in the author's opinion ample, assuming that the rock-breaker is well maintained.

In estimating the probable cost of rock-breaking over a period of years, allowance must be made, of course, for periodical docking and painting, but the ram constitutes the heaviest item of maintenance, owing to the wear by abrasion of the bottom 2 or 3 ft. There is, also, the liability of the ram fracturing, in the course of time, due to "fatigue." Messrs. Lobnitz and Co. state, as the result of their general experience, that the total cost of repairs and renewals will not exceed that of all the other working expenses put together, and the author believes this to furnish a safe basis for an estimate. Hence:

For 27 weeks—

Average cost for wages, coal, stores, etc., as previously ascertained	$2,970.43
The estimated allowance for cost of repairs and renewals (including periodical docking and painting), based on Messrs. Lobnitz and Co.'s estimate, can therefore be put at the maximum figure of	2,970.43
Interest, depreciation and insurance, as above	1,459.95
Estimated total cost	$7,400.81

Hence the estimated total cost of breaking rock, including interest, depreciation, etc., is

$$\frac{\$7,400.81}{24,535} = \$0.3016 \text{ per cu. yd.}$$

The average cost of drilling and blasting sandstone rock at Blyth was $0.72 per cu. yd. The drilling craft consisted of a barge, upon which was mounted a derrick and overhanging platform, an ordinary vertical boiler and a winch engine. The drills, six in number, were worked by hand, assisted by ropes attached to the drill crossheads, and led over sheaves at the top of the derrick to barrels upon a long shaft driven by the winch. The winch was kept continuously running, and the lifting and releasing of the drills were effected by alternately tightening and slackening two or three turns of the rope around each barrel. Belliite was the explosive used, and an average of about 488 cu. yds. of rock per week were broken, the craft working night and day.

In comparing the removal of large quantities of rock by the rock-breaker and by blasting, the following are the chief points in favor of the rock-breaker, viz.: (1) Considerably less cost; (2) the rock is broken at a quicker rate; (3) the rock is broken to a more convenient size for dredging, so as to increase the rate of the latter operation by about 15%; (4) the rock can be broken at places where it would be injudicious to use explosives; (5) freedom from the danger incidental to the use of explosives.

The engineers to the Blyth Harbor Commissioners are Messrs. J. Watt Sandeman and Son, of Newcastle-upon-Tyne, and the author is the Resident Engineer.

In a recent review of the work of the Lobnitz Rock Breaker, "Le Génie Civil" gives some figures which may be compared with those compiled by Mr. McGlashan, although the absence of unit prices and other details of the work noted in the French journal takes most of the value from the comparison. In the Manchester Canal work, which was in an easily-broken, friable rock, operations over ten months gave the following results:

Rock broken up per month of 480 working hours:	
Average	6,400 cu. yds.
Maximum	10,180 cu. yds.
Minimum	5,620 cu. yds.
Cost of operating machine per month:	
Wages	$540
Coal, water, etc.	135
Maintenance	525
	$1,200

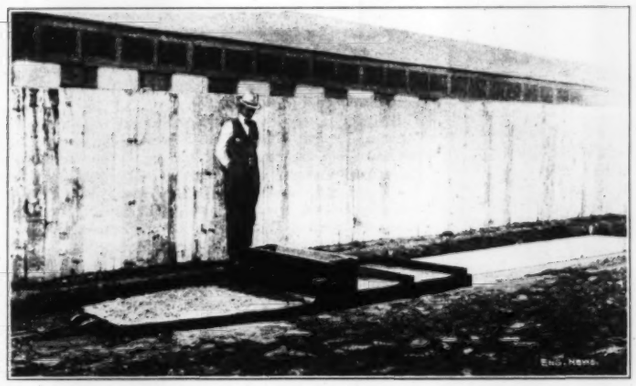
The average work per day was a depth of two feet over an area of 120 × 36 sq. ft. Comparing this hourly average breaking capacity with that noted at Blyth, it will be seen that the Manchester work averaged about 13.3 cu. yds. of rock per hour at a cost of 18.8 cts. per cu. yd., while the Blyth work was 1,177 cu. yds. in a week of 132 hrs., or 8.9 cu. yds. per hour at a cost of 23 cts. per cu. yd. It is stated in "Le Génie Civil" that in French practice subaqueous rock may be broken up by the Lobnitz machine at a rate of 3 cu. yds. per hr. in hard granite,

5 to 6 cu. yds. per hr. in gneiss and 10 cu. yds. per hr. in soft schist.

It should be noted that all of the above data relate entirely to the breaking up of the rock and do not deal at all with the costs and details of the subsequent necessary dredging and removal.

A CONCRETE SIDEWALK MACHINE.

In the accompanying half-tone there is shown a traveling mold, recently invented by Mr. Ernest L. Ransome, which is used for the almost automatic construction of concrete sidewalks, unit slabs, lintels or other members having a uniform cross-section. The mold is to be placed on the site of construction and drawn ahead by power, leaving the finished product behind it. Mass concrete for the base of a sidewalk, for instance, is filled in the front part of the mold and the finishing or top mortar coat in the middle hopper, and as the mold is drawn along the hopper is so designed that it feeds a thin layer of mortar onto the concrete base. It is stated that no skilled finishers are required with the mold, but that a smooth top coating and solid foundation are automatically produced, at a speed of about 2 ft. per min.



A MOLDING MACHINE FOR BUILDING CEMENT SIDEWALKS.
(Invented by Mr. Ernest L. Ransome, Assoc. Am. Soc. C. E.)

The manufacturer and owner of the device, who has furnished us with this information, is the Ransome International Conduit Co., of No. 11 Broadway, New York.

POWER REQUIREMENTS OF RAILROAD SHOP TOOLS.*

By L. R. POMEROY,† Assoc. M. Am. Soc. M. E.

Generally speaking, for railroad repair shops, the generator capacity approximately equals 15 KW. per locomotive pit, or space in erecting shop occupied by one locomotive. This comprehends requirements for tools, cranes, heating, blower and exhaust fans, i. e., provides for all power required except lighting. The tools alone require about 9 to 10 KW. per pit; heating, blower and exhaust fans 5 KW. per pit, while 3 KW. per pit will care for the ordinary shop and adjacent yard lighting. If power is required for lighting terminal yards, buildings, etc., in addition to shop requirements, an increase in generator capacity must be made to cover such contingencies. The curves, Figs. 1 to 13, are submitted to cover the general horsepower requirements of machine tools ordinarily found in railroad repair shops.

Occasionally certain tools are selected with the purpose of performing extra heavy service, to utilize the full capacity of the new rapid cutting tool steel, as is now done in manufacturing shops; in such cases the power to drive must be figured on the basis of service required of the machine. As these cases are few and exceptional the curves meet the majority of conditions, but the exceptions can be taken care of by the following formula:

HP. to drive equals $F \times D \times$ (F.P.M.) $\times 12 \times N \times C$.

Where F = Feed in ins.; D = Depth of cut in ins.; (F.P.M.) = Ft. per min.; N = Number of tools cutting; C = constant depending on the class of material, with the folloowing values:

For cast iron	0.35 to 0.5
Soft steel or wrought iron	0.45 to 0.7
Loc. D. W. tires	0.70 to 1.00
Very hard steel, i. e. crucible steel D. W. tires	1.00 to 1.10

This formula is based on Prof. Flather's dynamometer tests which check up fairly with actual motor tests, and is, therefore, submitted with confidence. For example: The aggregate HP. of 45 tests, with various tools, by test was 247.7, while the calculated aggregate HP. by formula equals 247.2.

The extensive tests made by Dr. Nicolson, of the Manchester Technical School, England, confirms the foregoing, and is a very interesting contribution to the subject. A careful analysis of the results of these experiments show the average HP. required at the motor, per pound of metal removed per minute to be as follows:

(1)—Medium or soft steel or wrought iron.... 2.4 HP.
(2)—Hard steel ..... 2.65 HP.
(3)—Cast iron, soft or medium ..... 1.00 HP.
(4)—Cast iron, hard ..... 1.36 HP.

Using the symbols of previous formula the HP. becomes: $F \times D \times$ (F.P.M.) $\times 12 \times N \times W \times$ figures above, where W equals the weight of a cubic inch of metal removed, and is as follows: For cast iron 0.258; wrought iron 0.278; for steel 0.284.

The following examples illustrate more or less heavy cuts to which reference has been made; the larger powers given are exceptional, while the average requirements are far below these, and all are submitted as actual cases which have come under the writer's observation.

(a)—*100 inch driving wheel lathe*—(material steel D. W. Tires.)
$\frac{5}{16}$ in. feed $\frac{5}{16}$ in. cut at 18.5 F.P.M.—two tools cutting.
$\frac{5}{16} \times \frac{5}{16}$ in. $\times$ 18.5 ft. $\times 12 \times 2 \times C. = 40$ HP.
Same lathe $\frac{3}{16}$ in. feed—$\frac{1}{4}$ in. cut—at 16 F.P.M. Two tools cutting.
$\frac{3}{16}$ in. $\times \frac{1}{4}$ in. $\times$ 16 ft. $\times 12 \times 2 \times C. = 16$ HP.

(b)—*Old 76 inch D. W. lathe*—(material D. W. tires)
$\frac{1}{16}$ in. $\times \frac{1}{4}$ in. $\times$ 16 ft. $\times 12 \times 2 \times C. = 5$ HP.
$\frac{1}{8} \times \frac{3}{4}$ in. $\times$ 30 ft. $\times 12 \times 3 \times 45$ (two tools cutting) $= 45$ HP.
Same machine boring D. W. tire
$\frac{1}{8}$ in. $\times \frac{3}{16}$ in. x 28 ft. $\times 12 \times 2 \times 1$ (two tools cutting) $= 15$ HP.

(g)—84 *inch boring mill* (on 62 in. cast-iron wheel centers)
$\frac{1}{8}$ in. $\times \frac{1}{10}$ in. x 30 ft. $\times 12 \times 3 \times 0.35$ (three tools cutting) $= 4.7$ HP.
Same mill boring 44 in. steel tire
$\frac{1}{4}$ in. $\times \frac{3}{32}$ in. $\times$ 26 ft. $\times 12 \times 2 \times 1$ (two tools cutting) $= 14.5$ HP.

(h—*A special test on an extra heavy D. W. lathe*, giving results representing unusual conditions, under which the operator was given a heavy bonus to develop the ultimate capacity of the machine, is:
Average feed 0.4625 in. $\times$ depth 0.0423 at 12.2 F.P.M. (two tools cutting).

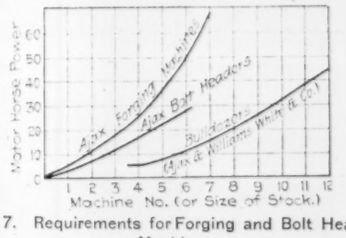


Fig. 7. Requirements for Forging and Bolt Heading Machines.

These figures are the averages of 37 tests and represent 40 HP. The maximum HP. developed was about 65. The machine is equipped with a 40-HP. D. C. motor with 2.1 speed variation. The lathe in question is a "special," extra heavy and about double the capacity and cost of the standard D. W lathe of equivalent size. On average work the same investment in two lathes will turn out more work in a year than this special machine.

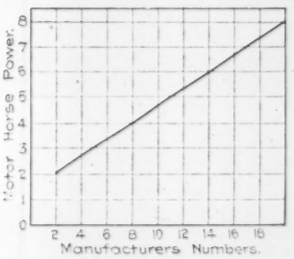


Fig. 8. Requirements for Pipe Threading and Cutting Machinery.
Bignal & Keeler and similar types.

For rapid estimates, where the foregoing data is not available, the HP. required can be obtained by the following formula:

(a) $$\text{HP.} = \frac{d \text{ in.} \times f \times \text{(R.P.M.)}}{12 \times 400}$$ (single belt)—

where d = Diameter of smaller pulley in inches; f = Face of pulley in inches; R. P. M. = Revolutions per minute.

(b.) $$\text{HP.} = \frac{d \text{ in.} \times f \times \text{(R.P.M.)}}{12 \times 400 \times 0.7}$$ (double belt).

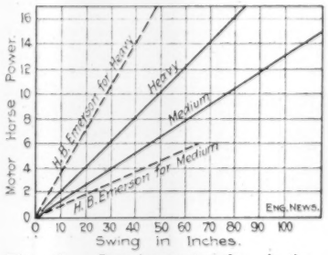
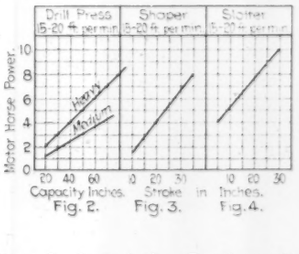


Fig. 1. Requirements for Lathe Motors.
(1 Tool Cutting Double Head Axle Lathe, 10 HP.; Driving Wheel Axle Lathe, 20-25 HP.)



Figs. 2, 3 and 4. Requirements for Drill Press, Shaper and Slotter.

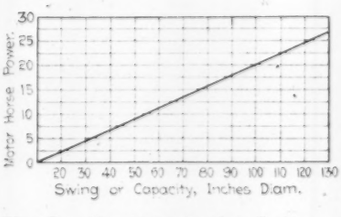


Fig. 5. Requirements for Boring Mills.
(1 Tool Cutting 20 ft. per min.)

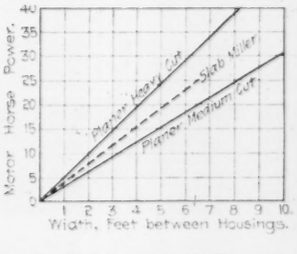


Fig. 6. Requirements for Planers.
(2 Tools, 15 to 20 ft. per Min.; Ratio of Cut to Return 1 to 3.)

(c)—*Steel tired wheel lathe* (engine truck wheels)
$\frac{1}{7}$ in. x $\frac{5}{16}$ in. $\times$ 16 ft. $\times 12 \times 2 \times C. = 17$ HP.

(d)—*Planer* (material cast iron)
$\frac{5}{32}$ in. $\times \frac{3}{8}$ in. $\times$ 16 ft. $\times 12 \times 0.35$ (one tool cutting) $= 4.5$ HP.
(two tools cutting) $= 9$ HP.

(e)—*Planer* (wrought iron engine frame)
$\frac{5}{32}$ in. $\times \frac{1}{2}$ in. $\times$ 16 ft. $\times 12 \times 2 \times .5$ (two tools cutting) $= 15$ HP.

(f)—*76 inch boring mill* (on cast steel D. W. centers)
$\frac{1}{8} \times \frac{3}{4}$ in. $\times$ 30 ft. $\times 12 \times 3 \times 45$ (two tools cutting) $= 45$ HP.
Same machine boring D. W. tire
$\frac{1}{8}$ in. $\times \frac{3}{16}$ in. x 28 ft. $\times 12 \times 2 \times 1$ (two tools cutting) $= 15$ HP.

(g)—84 *inch boring mill* (on 62 in. cast-iron wheel centers)
$\frac{1}{8}$ in. $\times \frac{1}{10}$ in. x 30 ft. $\times 12 \times 3 \times 0.35$ (three tools cutting) $= 4.7$ HP.
Same mill boring 44 in. steel tire
$\frac{1}{4}$ in. $\times \frac{3}{32}$ in. $\times$ 26 ft. $\times 12 \times 2 \times 1$ (two tools cutting) $= 14.5$ HP.

(h—*A special test on an extra heavy D. W. lathe*, giving results representing unusual conditions, under which the operator was given a heavy bonus to develop the ultimate capacity of the machine, is:
Average feed 0.4625 in. $\times$ depth 0.0423 at 12.2 F.P.M. (two tools cutting).

This formula is very conservative and provides for about as much overload capacity for belts as is ordinarily assumed for motors. This formula considers a liberal allowance for the influence of centrifugal force and diminishing arc of contact of pulley figured, driven from a larger one.

This formula is especially useful in figuring power required for wood working machines and was arrived at largely from experience with such machines.

Another formula, adapted from Ruleaux, giving somewhat higher values, is preferred by some, as it con-

*Abstract from paper read before the Central Railway Club May 8, 1908, at Buffalo, N. Y.

†Assistant to the President of the Safety Car Heating & Lighting Co., 2 Rector St., New York City.

siders the thickness of the belt. In this case the allowance for centrifugal force and arc of contact, less than 180 degrees, is taken care of by the selection of values for the constant "C."

HP. $= t$ in. $\times w$ in. $\times$ (F.P.M.) $\times C$, or if the R.P.M. and not the F.P.M. is known:

$$\text{HP.} = \frac{t \text{ in.} \times w \text{ in.} \times d \text{ in.} \times (\text{R.P.M.}) \times C}{4}$$

when t = Thickness of belt in inches; w = Width inches; d = Diameter of pulley inches; c = A constant of following values:

Leather belt		0.0092 to 0.0098
Cotton		0.0036 to 0.0068
Rubber		0.0050 to 0.0082

The tool builders do not always discriminate between the requirements of manufacturing plants and railroad repair shops and for this reason motors are often recommended that are larger than necessary. For example—the finished product of the axle departments of such concerns as the United States Steel, Midvale, Bethlehem and Cambria companies becomes the raw material for railroad shops. In the former case, the forging is turned out from the hammer without much regard to finished dimensions, as it is much cheaper to rough out to size on special rapid reduction lathes than to attempt to reduce to size under the hammer.

For such machining high power is required, but for same lathes for railroad shops, when the work performed is finishing on journals and wheel seats, mainly finishing cuts, a smaller and cheaper motor can be selected.

As an example of extreme requirements, as mentioned, the Bement-Niles lathe furnished the Howard Axle Works is given. The capacity of this machine is two cuts each $\frac{5}{8}$ in. $\times$ $\frac{1}{4}$ in. at 60 ft. per minute and at this rate of cutting will require a 60-HP. motor.

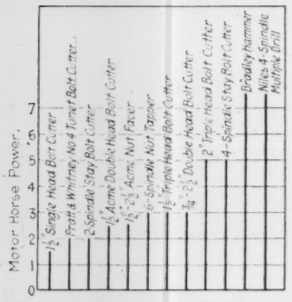


Fig. 9. Bolt and Nut Machinery, Helve Hammers, Etc.

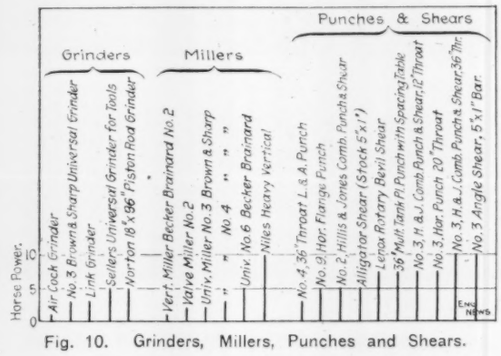

Grinders
Millers
Punches & Shears
Horse Power.
0
5
10
Air Cock Grinder
No. 3 Brown & Sharp Universal Grinder
Link Grinder
Sellers Universal Grinder for Tools
Norton 18 x 96 Piston Rod Grinder
Vert. Miller Becker Brainard No. 2
Valve Miller No. 2
Univ. Miller No. 3 Brown & Sharp
" " No. 4 " "
Univ. No. 6 Becker Brainard
Niles Heavy Vertical
No. 4, 36" Throat L. & A. Punch
No. 9 Hor. Flange Punch
No. 2, Hilles & Jones Comb. Punch & Shear
Alligator Shear (Stock 5"x1")
Lewis Rotary Bevil Shear
36" Mult. Tank Pl. Punch with Spacing Table
No. 3, H. & J. Comb. Punch & Shear, 12" Throat
No. 3, Hor. Punch 20" Throat
No. 3, H. & J. Comb. Punch & Shear, 36" Throat
No. 3 Angle Shear, 5"x1" Bar
ENG NEWS

Fig. 10. Grinders, Millers, Punches and Shears.

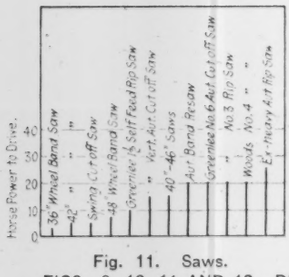


Fig. 11. Saws.

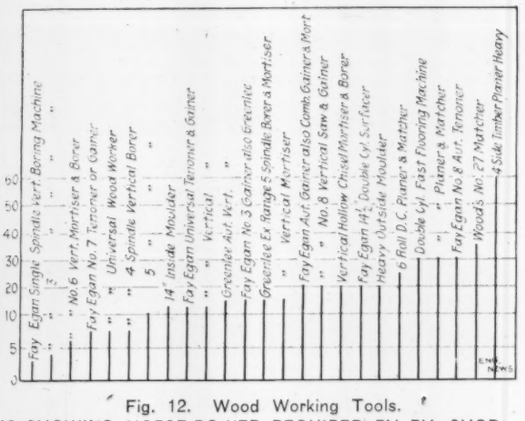

Horse Power to Drive.
0
5
10
20
30
40
50
60
Fay Egan Single Spindle Vert. Boring Machine
" " " "
" " No. 6 Vert. Mortiser & Borer
Fay Egan No. 7 Tenoner or Gainer
" Universal Wood Worker
" 4 Spindle Vertical Borer
" " 5 " "
" 14" Inside Moulder
Fay Egan Universal Tenoner & Gainer
" " Vertical " "
Greenlee Aut. Vert. " "
Fay Egan No. 3 Gainer also Greenlee
Greenlee Ex Range 5 Spindle Borer & Mortiser
" Vertical Mortiser
Fay Egan Aut. Gainer also Comb. Gainer & Mort
" " No. 8 Vertical Saw & Gainer
Vertical Hollow Chisel Mortiser & Borer
Fay Egan 14" Double Cyl. Surfacer
Heavy Outside Moulder
6 Roll D. C. Planer & Matcher
Daddie Cyl. Fast Flooring Machine
" " Planer & Matcher
Fay Egan No. 8 Air. Tenoner
Woods No. 27 Matcher
4 Side Timber Planer Heavy
ENG NEWS

Fig. 12. Wood Working Tools.

FIGS. 9, 10, 11 AND 12. DIAGRAMS SHOWING HORSE-POWER REQUIRED BY RY. SHOP MACHINE TOOLS.

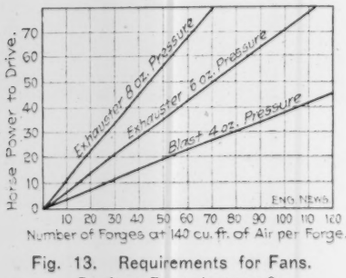


Fig. 13. Requirements for Fans.

$$\frac{\text{Cu. ft.} \times \text{Press. in oz.} \times 9}{33{,}000 \times 45\% \text{ Eff.}}$$

Another machine built for same work used largely in axle shops and in many railroad shops is capable of taking two cuts of $\frac{3}{4}$ in. $\times$ $\frac{1}{12}$ in. at 24 F.P.M. requiring 18 HP. and is usually furnished with a 20-HP. motor.

While this power is all right for full capacity of machine, 10 HP. will cover the requirements of same tool on average railroad shop work.

Number of pits required =

$$\frac{\text{(Total No. eng.)} \times \text{(Avg. days in shop)}}{300 \text{ (No. working days in year)}}$$

Example: 400 engines, avg. days in shop 25.

$$\text{Number of Pits} = \frac{400 \times 25}{300} = 33$$

$$\text{Capacity per year} = \frac{\text{No. pits} \times 300}{\text{Avg. days in shop}}$$

In order to reduce the average number of days in shop to about 20 for general overhauling it is estimated that the machine shop adjacent to the erecting shop should contain seven machine tools per engine pit, and floor area to accommodate seven tools per engine capacity should be about 1,500 sq. ft. per pit. Power required for air compressors equals the delivery in cubic feet of free air per minute at 100 lbs. pressure of the compressor multiplied by 0.14. Modern erecting and machine shops including heating, cranes, etc., cost from $2.50 to $3.50 per square foot inside measurement.

Rate per KW. hour to cover fixed charges =

$$\frac{\text{Total fixed charges per year}}{\text{(Max. demand)} \times 8{,}760 \times \text{(load factor)}}$$

Illustration: Fixed charges = $8,330. Max. demand = 500 KW. Load factor = 33%.

$$\text{Then, rate} = \frac{\$8{,}330}{500 \times 8{,}760 \times .33} = 0.0057.$$

NOTES FROM ENGINEERING SCHOOLS.

McGILL UNIVERSITY.—Prof. Frank D. Adams has been appointed to the chair of geology.

PURDUE UNIVERSITY.—At the thirty-fourth annual commencement of Purdue University, the honorary degree of Doctor of Engineering was conferred upon Mr. Angus Sinclair, M. Am. Soc. M. E. Dr. Sinclair is the editor of the "Railway and Locomotive Engineering" journal, published in New York City, and is the author of several books on locomotive design and operation.

AN ACCIDENT IN TESTING A PENSTOCK killed three men at a new hydraulic power plant on the Löntsch River, Switzerland, on May 22. According to the "Schweizerische Bauzeitung" of May 30, not all of the penstock had yet been placed, but the section in place, 50 to 53 ins. in diameter, was being tested by pumping up to nearly 300 lbs. per sq. in., the greatest static head on this section after completion being 210 lbs. The lower end of each section tested was closed off by a $\frac{7}{8}$-in. blank head bolted to the penstock flange by 40 $1\frac{3}{8}$-in. bolts. While the pressure was being pumped up the head burst off, and the released water caught several persons standing below, among them the supervising engineer of the power equipment, Weinmann; the latter and two others were killed. It seems that most of the bolts of the blank head were torn off, but several at the lower edge held and the head remained attached to the pipe by these bolts.

IN THE COLLAPSE, DURING CONSTRUCTION, of the floor system of an apartment house in Washington, D. C., two men were killed on June 9 and several others injured. The floors were reinforced-concrete slabs spanning between steel beams which in turn rested on bearing brick walls. The exact cause of the collapse, which started on the highest floor completed, the fourth, is uncertain, but many features regarding the design and construction of the building are out of the ordinary and an official investigation about to be started should throw some light on the question. The building was originally designed as five stories high, but subsequently was increased to six, with the consent of the building department of the city. It was provided that the additional weight of the sixth story should be cared for by interior steel wall columns under the ends of all floor beams and not by any thickening of the brick walls. These strengthening columns had not been put in at the time of the accident, but this neglect could hardly have resulted in collapse because a large part of the dead load and all of the live load was not upon the building at that time; the walls themselves should have been amply strong. The two tenable theories of the failure are that the concrete floors were of poor construction and weakly supported, or that the floor system followed so closely upon the brick walls that the latter, with its unset mortar, could not resist the impact of the tamping on the concrete floors.

There was held the usual bootless coroner's inquest, at which the jury, possibly influenced by a demand for action from President Roosevelt, brought in a wholesale accusation against the city's inspector of buildings for approving the plans; the foreman of ironwork, for improper construction; the brick contractor, for hasty construction and use of poor material; and the owner of the building, on general principles. Why the concrete contractor was neglected is not known, for the testimony as reported was equally as unfavorable to him as to the other contractors. The case has now gone to the grand jury and after their decision it is understood that the District Commissioners will institute an investigation of the building department of the city with a view toward revising the building laws of the city.

GOVERNMENT TESTS OF RAILWAY SAFETY APpliances are provided for in the Sundry Civil Appropriation bill just enacted by Congress. The section reads as follows:

Hereafter the Interstate Commerce Commission shall be, and is, hereby authorized, at its discretion, to investigate, test experimentally, and report on the use and need of any appliances or systems intended to promote the safety of railway operation which may be furnished in completed shape to such Commission for such investigation, and test entirely free of cost to the Government. For this purpose the Commission is authorized to employ persons familiar with the subject to be investigated and tested, and may also make use of its regular employees for such purposes.

THE CONSTRUCTION OF FOOTBRIDGES FOR THE Manhattan suspension bridge across the East River at New York City was begun on June 15 by the operation of swinging a $1\frac{3}{4}$-in. wire cable between the Manhattan and Brooklyn towers. Sixteen of these small cables are to be placed, four in a group, thus giving four composite cables to carry two footbridges. From each footbridge the "spinning" of two of the four main cables will be handled.

The $1\frac{3}{4}$-in. cables are put in position by the following procedure: The cable, mounted on a reel placed on a scow, is brought alongside one of the towers, say the Manhattan tower. Its end is unreeled and carried up to the top of the tower, over a specially provided roller saddle, there mounted, and thence to the anchorage, where it is made fast. Then the scow is towed across the river, laying the cable along the bottom, to the opposite tower. Four of the $1\frac{3}{4}$-in. cables were brought to this stage of their erection on Friday, June 12. The remainder of each cable was then unreeled and coiled on the deck of the scow. On Monday, June 15, the free end of one of the cables was hauled up by a line to the top of the Brooklyn tower, over a roller saddle, and thence drawn down to the Brooklyn anchorage, its middle rising up out of the water during this operation and

coming up to the desired position. River traffic was delayed about half an hour during this work, and as the river traffic is heavy only one such interruption per day is thought advisable. The second cable was raised up out of the water in the same manner on the following day, and the third and fourth are to be raised on June 17 and 18. On Friday, June 19, the same order of operations will be begun with the second set of four cables, and so on, allowing a total period of four weeks for getting the 16 cables in place. When the cables are made fast at the Brooklyn anchorage they are socketed and drawn up to the precise deflection desired, as determined by levels.

The contractors for the erection of the main cables, of which the construction of the footbridges forms part, are the Glyndon Contracting Co., of New York, a corporation affiliated with the Carbon Steel Co., the subcontractor for the material and erection of the cables under the general contractors, the Ryan-Parker Construction Co. The Carbon Steel Co. has sublet the manufacture of the wire for cables and suspenders to the John A. Roebling's Sons Co., of Trenton, N. J., and the contract for the erection of the cables to the Glyndon company.

Mr. Holton Robinson, formerly of the Department of Bridges, of New York City, is Chief Engineer of the latter concern, and Mr. L. J. Gross is Superintendent of Erection.

A BRIDGE POOLING PROSECUTION in the State of Ohio ended on June 12 with pleas of guilty by eight bridge construction companies to the charge of conspiracy in restraint of trade. Each company was fined $250, an agent was fined $50, and the indictments against individual directors and officers of the companies were discontinued. The legal contest thus ended has lasted about three years. The prosecution was directed against a highway bridge "pool" of the kind that has long prevailed in the business of building county and town road bridges. The "pool" contemplated the attendance of agents of some or all of the several companies at each letting, a caucus of these agents before the letting at which the job would be awarded to one of the members in accordance with systematic allotment of work, and adjustment of the several bids to suit. The bids thus being based on a secret understanding, they were made high enough to yield a normal profit to the company to whom the work was allotted and in addition yield a fixed amount to each of the other companies in attendance.

THE EIGHT-TRACK RAILWAY DRAWBRIDGE over the Chicago Drainage Canal is to be replaced by a new structure. The present bridge is a double-leaf structure of the Scherzer type (Engineering News, May 24, 1900). Like all the other bridges over the canal, it was built as a fixed bridge to save expense, the intention being to apply the operating machinery when the canal was required for navigation. This work has been postponed from time to time, but the Sanitary District has now decided to equip the bridges with their machinery. This includes about 14 swing bridges and the eight-track bascule bridge. When the plans for equipping this last bridge were studied, it was found that the work would involve such extensive alterations that it would be cheaper to build a new eight-track single-leaf bascule, including its operating machinery. Mr. G. M. Wisner, M. Am. Soc. C. E., Chief Engineer, informs us that the saving due to building a new single-leaf bridge instead of fitting up the present double-leaf bridge will be probably about $25,000. It is estimated that all the bridges can be equipped with operating machinery in a little less than two years.

A NEW BRIDGE OVER THE NILE is to be built at Cairo (Egypt) to give the central part of the city more direct communication with the district across the river. It is of interest in that the draw-span will be of American design, the Scherzer rolling-lift type of bascule bridge having been adopted by the engineers.

The design of the bridge was one of the last pieces of work undertaken by the late Sir Benjamin Baker as consulting engineer to the Egyptian government. It will be about 700 ft. long, with four fixed spans of 170 ft. and a double-leaf bascule span. Between the trusses will be 47.3 ft. c. to c., carrying a 39-ft. roadway, with a double-track street railway of meter gage. Outside of the trusses will be two 10-ft. sidewalks. All the spans will have parallel-chord rectangular through trusses of the Warren type, with no verticals except the end posts. They are 26.73 ft. deep, with eight panels of 20.5 ft. At each panel point is a 5-ft. plate-girder floor beam and a latticed top strut or wind brace. Between the floor beams are plate-girder stringers carrying transverse I-beams. These support the buckle-plate floor, which is covered with a bed of concrete.

The bridge crosses the river at an angle of 64°, and the channel opening is 88.56 ft. clear width between the piers. The curved heels of the trusses of the draw span will roll on heavy plate-girders in the flanking spans of 62.4 ft. The counterweights are of concrete. This span will be operated by electricity, and the machinery is designed to open or close the bridge in less than 30 seconds. This rapid operation is in order to facilitate the heavy traffic upon the bridge and in the river.

The abutments and piers will be founded on pneumatic caissons, sunk to almost 93.5 ft. below low water. The contract for the bridge has been awarded to the Fives Co., of Lille, France, with the Scherzer Rolling-Lift Bridge Co., of Chicago, Ill., as engineers for the draw span.

A FLAT STEEL ARCH OF LONG SPAN is employed in a new highway bridge over the Neckar River at Mannheim, Germany. The main part of the bridge consists of three arches, the middle of which is a two-hinged steel rib arch of 374 ft. span between abutments or 371 ft. between centers of hinges, with rise of 22.8 ft. c. to c., while the arch on either side is a three-hinged concrete barrel arch of 195 ft. clear span or 192 ft. span c. to c. and 18.1 ft. rise c. to c. The steel arch has a parabolic shape of rib. Its ratio of span to rise is 16.3. It comprises four ribs, each of which is of box-girder section, with lower side open. Steel columns transfer the roadway load to the arches. The concrete arches, whose ratio of span to rise is 10.6, have cut-stone spandrel walls, while in the interior the roadway is carried by square reinforced-concrete columns footing on the arch ring. The concrete arches have the peculiarity that the landward spring-line is 4¼ ft. lower than the riverward spring-line, the alinement of the arch thus approximately following the grade of the roadway (2.7% upward toward midstream). The deck, which is 49 ft. in the clear between hand-rails (33 ft. roadway, two 8-ft. sidewalks), consists of I-beam longitudinals connected by a 5½-in. reinforced-concrete slab. The bridge was begun late in 1906, and opened for traffic in February, 1908. Its cost, roughly computed, is about $390,000, exclusive of real estate and approaches. (Zentralblatt der Bauverwaltung, May 20, 1908).

THE NIAGARA FALLS POWER CO., on June 14, shut down its plant, on the American side of the river, for several hours following the plans mentioned in our issue of June 11. The abutment of the upper steel arch bridge, which it was feared was endangered by the wash of the water from the power company's tunnel, was examined and found practically undamaged by this water. It was found, however, that a concrete guard wall, which had been founded on the somewhat loose rock dumped in building the tunnel, had been considerably undermined. As the whole guard wall could be carried away without immediate danger to the abutment this will probably be repaired at leisure. At the time of the shut down the tunnel and wheel pits of the Niagara Falls Power Co. were examined and it is reported that the brick lining was found intact and not eroded. To enable government engineers to make observations on the Niagara River the gates on the canal of the Niagara Falls Hydraulic Power and Manufacturing Co., were closed. This stopped the drainage of water for power on the American side, and it is stated that the water level at the brink rose only 1-10-in. Major C. W. Kutz, Corps of Engineers, U. S. A., member of the committee of landscape architects in connection with the preservation of the natural scenic effect at Niagara, was reported in charge of these observations.

THE INTERNATIONAL WATERWAYS Commission, in a report to the Canadian Parliament on June 5, recommended that the United States Government prohibit the diversion of water from the Great Lakes through the Chicago Drainage Canal in excess of 10,000 cu. ft. per second, that amount being considered sufficient for the sanitary purposes of the city for all time and providing for the largest navigable waterway from Lake Michigan to the Mississippi River which has been considered by Congress.

The amount by which the mean level will be lowered by the discharge of 10,000 cu. ft. through the canal is estimated at about 6 ins. in lakes Huron and Michigan and about 5 ins. in Lake Erie and 4 ins. in Lake Ontario.

Any further diversion, the commissioners say, would mean the expenditure of a very large amount of money to restore depth in both American and Canadian harbors and to maintain a uniform draft of 14 ft. in the Canadian canal system.

With respect to the proposal to erect a dam or dams in the Niagara River with a view to maintaining the level of Lake Erie, the commission has agreed that no works would be authorized which would lower the levels in Lake Ontario or the St. Lawrence River.

The commissioners make some important recommendations with regard to the question of power development at Niagara Falls and restriction of the amount of water to be taken on both sides of the falls by the various power companies.

After briefly reviewing the history of the agitation to preserve the scenic effects of the falls, and noting that so far only two companies in New York State and three on the Canadian side of the river have actually constructed works, the commissioners refer to the other proposed power development schemes on each side of the river for which charters had been granted, under which water in unlimited quantities could have been taken at points above the falls.

All these proposed developments, the commissioners say, would affect more or less seriously the level of Lake Erie and all are objectionable. The commission reached the following conclusions:

(1) That it would be a sacrilege to destroy the scenic effect of the Niagara Falls.

(2) More than 36,000 cu. ft. per second on the Canadian side of the Niagara River and 18,500 cu. ft. per second on the United States side, including diversions for power purposes on the Erie Canal, cannot be diverted without injury to Niagara Falls as a whole. The commission, therefore, recommend that the diversion of water be limited to these amounts respectively.

The Canadian section of the commission dealing with the situation as it affects the three companies now established on the Canadian side, say it would have been wise if development had been limited to the generation of electricity for distribution in Canada. In that case there would have been one corporation up to this time which would have fully supplied the Canadian market.

The three Canadian companies are now permitted to develop a total of 400,000 HP. and according to a Canadian act passed last year governing the export of electricity they are compelled to take care of the Canadian market to the extent of at least one-half of the power generated.

THE RAILWAYS OF SOUTH AFRICA comprise three principal systems: the Cape Government Railways, the Natal Government Railways and the Central South African Railways. The third is entirely in the interior, while the others serve different ports on the southeast coast, so that there is rivalry as to the distribution of the through traffic. In addition, there is the direct Portuguese line to the interior from the port of Lorenzo Marquez. Under these conditions each railway endeavors to obtain for itself a large share of the traffic.

Under the present government steps have been taken towards a future unification of the railways in one system, and the three railway systems noted above agreed to the appointment of a commissioner to study the question of traffic distribution between the ports and the interior from a purely railway point of view, in order to determine the best rates as regards grades, cost of operation and efficiency of service. He was to consider the question from two points of view: 1, under present conditions, where each through route is owned and operated by two or more colonial administrations or governments; 2, under the assumption that the railways of British South Africa were owned and operated by one administration, so that no considerations would arise as to the distribution of revenue between the existing separate administrations.

Mr. J. Conacher was appointed commissioner, and his report has recently been issued. Test trains, with 268 gross tons of freight, were operated on the several routes, the gross weight of the trains ranging from 422 tons to 453 tons, owing to differences in the equipment and the style of engine required. The conditions of traffic, operation and revenue were all investigated, as well as the relative merits and commercial advantages of the several ports. Mr. Conacher arrives at the conclusion that only by unification of the railways and harbors under one administration can the future distribution of sea-borne traffic be arranged satisfactorily.

FILTRATION OF TORONTO'S WATER SUPPLY at an estimated cost of $750,000 has been recommended by a commission. The estimate is for a supply of 40,000,000 gallons daily.

FILTRATION VINDICATED.—According to statistics which have been compiled at City Hall there has been a decrease of 75% in the prevalence of typhoid fever since the filtration plant was put into operation. As the plant has not been operating to much more than one-half of its capacity, it is plain that when it is completed Pittsburg may confidently expect to lose its pre-eminence as typhoid headquarters and practically wipe out a plague which in the last ten or fifteen years has cost it the lives of thousands of its citizens.—Pittsburg Press, May 20.

THE NEW FILTER PLANT FOR NEW ORLEANS is expected to be completed and in operation by the close of the present year. As described in the 16th semi-annual report of the Sewerage and Water Board just issued, the water taken from the Mississippi is first passed through grit reservoirs where it remains an hour for the heavier sediment to settle. It then passes to four coagulating reservoirs with a combined capacity of 30,000,000 gallons, where it is treated with lime and sulphate of iron. A further large amount of the solid contents is here removed by settling and the clarified water passes to the filters. There are ten filters, each with 1,431 sq. ft. of sand area and a maximum capacity of 6,000,000 gallons per day. The filtered water is pumped directly into the distribution mains, but at

hours when the consumption is low, the water is accumulated in two clear water reservoirs holding 15,000,000 gallons.

AUTOMOBILE STREET SWEEPERS were introduced in Paris about two years ago and have been in use during that time, in competition with the ordinary horse-drawn vehicles, with very satisfactory results. The machines are gasoline-driven, two-cylinder, 15-HP. automobiles, with a body 14.5 ft. long and 7.2 ft. wide. The brush is hung about midway between the forward and back axles, at an angle of 52° with the longitudinal axis of the machine. This brush is 7 ft. long, sweeping a path about 6 ft. in width. Attached to the chassis of the automobile is a large cylindrical tank holding about 1,000 gals. of water, so that the sweeper may be used as a street sprinkler either simultaneously with the sweeping operation or by itself. Extensive tests as to the relative efficiency and cost of the horse-drawn and automobile sweepers have been carried on during the time that the latter have been in use. It was found that the automobile was much more thorough in its work than the horse-driven sprinkler, principally because of the wider area covered by the automobile machine on account of the greater force gained in pumping the stream. The following comparative tests were reported by M. E. Bret, in "Le Génie Civil," April 18 and 25, 1908: On the automobile machine, when used for sweeping, the speed at times reached as high as 10 miles an hour, but the average was reduced to about 5.4 miles per hour by stopping and slowing down on account of the congestion of traffic in the streets, and also from the time taken out for lunch in the middle of the day. The width of the single strip swept was about 6 ft., the surface covered each day reaching approximately 120,000 sq. yds.; this area being reached by deducting one-sixth of the total area covered by the machine, on account of the overlapping of the adjacent strips. Under the same conditions, the horse-drawn sweeper was able to sweep daily a length of 13 miles over a strip 5.5 ft. wide, making a total surface of about 42,000 sq. yds. It will thus be seen that the automobile machine daily did about as much work as three horse-drawn machines. In sprinkling, the advantage of the new device was not so pronounced. The mean speed of the automobile on this work was about 4½ miles per hour, this reduced speed being due to the time taken up in refilling the tank, which took about 12 minutes each time, and in a day was performed about 22 times, using 15,000 gals. of water. With the horse machine the maximum water used was 23 tanks full, each carrying 320 gals., or a total of about 7,300 gals. The average, however, with the horse machine, was about 4,470 gals., or about one-third that of the automobile. The automobile used about 7.9 gals. of gasoline for a day's trip of 34 miles.

The following two tables give the relative costs of the two machines for the same amount of work:

AUTOMOBILE.

	Sweeping.	Sprinkling.	Average.
Daily expense	$4.81	$3.93	
Depreciation	3.30	2.20	
	$8.11	$6.13	$7.12

SWEEPING AND SPRINKLING WITH HORSE MACHINES. (Three Machines.)

Labor and Team	$7.30
Depreciation	.40
Lubrication	.06
	$7.76

The final advantage seems to lie with the automobile machine, notably in the sprinkling costs, for in that the actual work on the machine is less than in sweeping, on account of the suspension in the use of the gasoline and the wear on the tires during extended refilling of the tank. In these costs given above, each element enters in the following proportion: Salary of the mechanician, 30%; gasoline, taxes deducted, 27%; lubrication, 4%; depreciation in the automobile (not including tires), 18%; depreciation and renewing of tires, 21%. The development of the automobile within the last two or three years undoubtedly will greatly reduce these figures for the machine-driven sweeper and sprinkler, but even as they now stand the municipality of Paris is satisfied that the using of automobiles is an economical practice in the sweeping and sprinkling of the streets.

Considerable attention was paid to the brushes used on the automobile machines. Attempts were made to substitute steel wires for the ordinary rattan bristles, but difficulty was found in getting a steel wire of sufficient elasticity to serve the purpose. Most of the steel wire tested acquired a permanent bend after a few weeks' use. In addition it soon rusted and wore out under the combined effect of the weather and the friction.

THE PRICE OF ELECTRIC CURRENT IN BOSTON for lighting will hereafter be 12 cts. per KW.-hr., with a minimum meter charge of $1 per month. This is the result of a recommendation by the Massachusetts Gas and Electric Light Commission, and is in effect a reduction from the differential rates resulting from a very complicated system of charging. The contention of the Commission has been that the Boston Edison Company's differential rates were unlawful to a certain extent because discriminating and not proven to have been based on cost. While the company does not admit the contention about the differential rates, it has agreed to the reduction recommended and the new rates will become operative July 1.

A NEW TYPE OF CABLE for electric-power transmission has been developed in England and is described in our British contemporaries, "The Electrician" and "Electrical Engineering" of May 29 and 28, respectively. These cables have as insulation usually paper wrappings impregnated with a new substance called "liconite," which is a black, plastic substance of a bituminous nature. It is claimed that this material is cheap, is not affected by dilute acids, alkalies, oils, moisture, is not subject to electrolysis, is non-hygroscopic, withstands large temperature changes, is tough and plastic, does not flow or crack and has a high dielectric strength. With this composition lead sheaths usually may be left off. A length of cable composed of 0.25-sq. in. stranded copper core, covered with 56 layers of "liconite" impregnated paper (total thickness, ⅝-in.), with two layers of "liconite" tape and with a single layer of Hessian tape, was soaked in water for 12 days and stood 30,000 volts, between core and water, for five minutes. A two-yard length, cut from this cable, was bent around an 18-in. drum three times in each direction and broke down at 70,000 volts. Other sizes and constructions gave similar results.

AN EXAMPLE OF POWER CENTRALIZATION in accord with modern engineering practice is afforded by the reconstruction of the surface plant of the Copper Queen Consolidated Co. at Bisbee, Arizona, as described in the "Mining and Scientific Press" of San Francisco, Cal. In connection with a complete change of the ore handling system, electrical equipment of the whole plant, underground as well as on the surface, with one central power development station, is in course of installation and now almost completed. The property consists of five shafts hitherto incompletely connected, and each possessing its individual steam plant and system of slow and expensive hand and mule power ore transportation system. Following the reconstruction plan, one shaft, the "Sacramento," has been sunk to a depth of 1,200 ft. and is being connected with all workings, by main haulage drifts aggregating 5½ miles in length, through which electric motors will run at the rate of six miles per hour, carrying ten tons per trip. The ore on reaching the shaft will pass through 50-ton bins into large skips and, on reaching the surface will be taken by belt conveyors directly to the railway cars. At the Sacramento Shaft four 400-HP. water-tube boilers, using fuel oil, two cross compound air-compressors each rated at 3,500 cu. ft. free air displacement per minute, three 500-KW. vertical steam turbines generating an alternating current of 2,200 volts, and a double, compound, tandem, condensing, hoisting engine form the main units of the power station. The main hoist, a first-motion "Nordberg," with 7-ft. diam. and 5-ft. face cylindrical drums, and the air compressors whose power is designed to answer all requirements of rockdrills and of secondary hoists, will be operated directly by steam; the electric current will be in part immediately converted to 250-volt direct current for use of the underground haulage system, the rest distributed at high voltage and transformed as locally required by machine shop, sawmills, small underground hoists, blowers, lighting system, and all other smaller machinery.

PERSONALS.

Mr. W. J. A. London has accepted the position of Chief Engineer of the Terry Steam Turbine Co., of Hartford, Conn., succeeding Mr. C. E. Terry, deceased. Mr. London was at one time connected with the C. A. Parsons Co., of Newcastle, Eng.

Mr. Henry L. Gray, recently engineer of the Railroad Commission of the State of Washington, has opened an office as a consulting civil and mining engineer at 513 Chamber of Commerce Building, Tacoma, Wash.

Obituary.

Charles P. Corlett, President of the Corlett Engineering Co., who had just completed plans for the $2,000,000 Andrews Industrial Home at Willoughby, Ohio, killed his wife and himself, June 9, at Willoughby.

J. G. Wagner, founder of the Milwaukee Bridge & Iron Works which, in 1900 became part of the American Bridge Co., died in Milwaukee, Wis., June 1, at the age of 74. He was born in Germany and came to America in 1855.

E. L. Berthoud, designer of the Georgetown Loop on the Colorado & Southern Ry., locating engineer on the original Union Pacific Ry. surveys, and one of the first engineers on the Panama Ry., died June 13 at his home in Golden, Colo., at the age of 83.

William J. Murphy, Vice-President of the Cincinnati, New Orleans & Texas Pacific Ry., and of the Alabama, Great Southern R. R., was stricken with paralysis at his home in Cincinnati, Ohio., on April 30, and died on Sunday morning, May 10. In 1887 he was General Superintendent of the Erie R. R.

Nathaniel Henry Crafts, City Engineer of Boston from 1864 to 1872, died June 14 after a protracted illness at his home in Stoughton, Mass. He first entered the office of William S. Whitwell, Chief Engineer of the Eastern Division of the Boston Water-Works, in 1849. After his resignation from the city's service he acted as consulting engineer.

ENGINEERING SOCIETIES.

COMING MEETINGS.

MASTER CAR BUILDERS' ASSOCIATION.
June 17-19. Annual convention at Atlantic City, N. J. Secy., Jos. W. Tayler, 390 Old Colony Bldg., Chicago.

AMERICAN RAILWAY MASTER MECHANICS' ASSOCIATION.
June 22-24. Annual convention at Atlantic City, N. J. Secy., Jos. W. Tayler, 390 Old Colony Bldg., Chicago.

AMERICAN SOCIETY OF CIVIL ENGINEERS.
June 23-26. Annual convention at Denver, Colo. Secy., C. W. Hunt, 220 West 57th St., New York City.

AMERICAN SOCIETY OF MECHANICAL ENGINEERS.
June 23-26. Annual convention at Detroit, Mich. Secy., C. W. Rice, 29 West 39th St., New York City.

SOCIETY FOR THE PROMOTION OF ENGINEERING EDUCATION.
June 23-26. Annual meeting at Detroit, Mich. (In connection with convention of American Society of Mechanical Engineers.) Secy., A. L. Williston, Pratt Institute, Brooklyn, N. Y.

AMERICAN SOCIETY FOR TESTING MATERIALS.
June 23-27. Annual meeting at Atlantic City, N. J. Secy., Edgar Marburg, University of Pennsylvania, Philadelphia.

AMERICAN INSTITUTE OF ELECTRICAL ENGINEERS.
June 29-July 2. Annual convention at Atlantic City, N. J. Secy., Ralph W. Pope, 33 West 39th St., N. Y.

AMERICAN SOCIETY OF HEATING AND VENTILATING ENGINEERS.
July 24-25. Summer meeting at Niagara Falls, N. Y. Secy., W. M. Mackay, P. O. Box 1818, New York City.

NEW ENGLAND WATER-WORKS ASSOCIATION.—The June meeting of the association will take the form of a summer outing to Plymouth, Mass., on June 24. Among the points of interest to be visited is the Plymouth Water Department's factory for cement-lined pipe; such mains have been in use here since 1855.

AMERICAN SOCIETY OF MUNICIPAL IMPROVEMENTS.—This society will postpone its next convention at Atlantic City, N. J., from Oct. 13-16, as previously announced, to Oct. 20-23, so as not to interfere with the meeting of another society which had first been fixed on the earlier date. Headquarters will be at the Hotel Dennis. Mr. A. Prescott Folwell, 512 Flatiron Building, New York City, is secretary.

INTERNATIONAL GOOD ROADS CONGRESS.—In answer to the official invitation of the French Government, formally requesting the United States to participate at the International Good Roads Congress to be held at Paris the week beginning Oct. 11, President Roosevelt has directed that this nation be strongly and officially represented; the following commission has been named: Logan Waller Page, Director of the Office of Public Roads, Chairman; Col. Charles S. Bromwell, U. S. Corps of Engineers, and Clifford Richardson.

AMERICAN RAILWAY ASSOCIATION.—In view of the rapidly increasing complications of modern railway relations and practice it has been deemed advisable to unite the various voluntary associations of railway officers under the control of the American Railway Association, and steps are being taken by the latter to accomplish this end. The work of the different organizations will thereby be harmonized and their recommendations will gain greatly in weight. A subcommittee of the executive committee of the American Railway Association has also considered the advisability of reorganizing the standing committees of that association and recommends their complete remodeling. The work of the present large number of temporary committees which have acquired a measure of permanence, is to be reapportioned among and supplemented by seven regular standing committees—on Transportation, Maintenance, Relations between Railroads, Electrical Working, Traffic Relations, Accounting and Statistical Inquiry and Legal and Economic Relations. Each of these committees will be divided into bureaus, as for example: the Committee on Relations between Railroads may sectionize its work according to the following activities, (a) Car Service, (b) Car Efficiency, (c) Arbitration, (d) Adjustment, (e) Transportation of Explosives, (f) Standard Cipher Code, etc. Under such a system unprecedented exigencies can be immediately met by the particular committee within whose field they come, without, as has hitherto frequently been the case, the appointment of a special commission for the adjustment of each new question.